2. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

This section presents the first screening stage of the PERA, in which existing, demonstrated remedial technologies and process options are compiled, listed, and evaluated for technical applicability. Identified technologies and process options cover a range of possible remediation approaches, referred to as general response actions (GRAs), and provide a number of potentially viable options capable of meeting project remedial action objectives (RAOs) and specific health-based and regulatory requirements (ARARs) for WAG 7.

2.1 Remedial Action Objectives

Under CERCLA (42 USC § 9601 et seq.), RAOs identify the results desired from a given remedial action to protect human health and the environment. The WAG 7 RAOs were developed in accordance with the "National Oil and Hazardous Substances Pollution Contingency Plan" (NCP) (40 CFR 300) and EPA guidance (EPA 1997; EPA 1988). The RAOs can generally be achieved by either reducing contaminant concentrations, immobilizing contaminants through treatment, or containing contaminants using protective administrative and physical barriers. An assumption for this PERA is that DOE or another government agency will retain control of the SDA in perpetuity and that final CERCLA actions will include capping and institutional controls to ensure protectiveness for contamination remaining at the RWMC.

Because RAOs are target objectives for cleanup activities, they offer a basis for evaluating a remedial alternative's capability to satisfy ARARs and protect human health and the environment. The RAOs specified for protecting human health and the environment are expressed in terms of both risk and exposure pathways and are achieved by reducing contaminant levels and restricting or eliminating exposure pathways. The RAOs identified for this analysis for human health and ecological receptors (specifically flora and wildlife) are presented in Figure 2-1.

Remedial Action Objectives for WAG 7

- Limit the cumulative human-health cancer risk for soil and groundwater exposure pathways to less than or equal to 1E-04
- Limit the noncancer risk for soil and groundwater exposure pathways to a cumulative hazard index of less than 2 for current and future workers and future residents
- Inhibit migration of contaminants of concern (COCs) to groundwater
- Inhibit ecological receptor exposures to COCs in soil and waste with concentrations greater than or equal to 10 times background values, resulting in a hazard quotient greater than or equal to 10
- Inhibit transport of COCs to the surface by plants and animals.

Figure 2-1. Remedial action objectives.

As discussed in Section 1.1, the PERA presented in this report focuses on remediating the source term within the SDA and does not assess specific remedial actions that address contamination previously released to the underlying vadose zone and groundwater. Therefore, in evaluating a remedial action's ability to achieve the RAOs, this PERA considers only influences of future contaminant releases from the source term.

2.2 Assumptions

The principal assumptions used in developing the PERA are these:

1. The PERA will address remediation of buried waste and contaminated soil down to the first basalt interface beneath the SDA. Remediation of groundwater and the vadose zone below the first soil/basalt interface will not be evaluated in the PERA. The OCVZ project is addressing volatile organic compounds (VOCs) in the vadose zone and groundwater.

2. The selected remedial alternative will include a cap over all or part of the SDA. Capping scenarios will include designs appropriate to local SDA conditions, including a biotic barrier.

3. Response actions will be limited to COCs identified in the ABRA (Holdren et al. 2002).

4. Estimates of maximum and average concentrations of the COCs in disposal locations will be based on disposal records and probing data.

5. Preliminary remediation goals will be based on carcinogenic risk of 1E-04 and a hazard index of 1.0. Remedial action will be implemented if media concentrations are greater than background values and one of the following conditions is true:

    a. Estimated carcinogenic risk is greater than 1E-04

    b. Estimated hazard index is greater than 1 for soil pathways, greater than 1 for the groundwater pathway, and greater than 2 for both pathways combined

    c. Simulated groundwater concentrations exceed maximum contaminant levels (MCLs).

6. Waste buried in the SDA before 1970 contains small quantities of irradiated fuel material. Soil vault rows contain high-activity, low-level waste, but no high-level waste.

7. The majority of the VOCs is buried in Pits 2, 4, 5, 6, 9, and 10.

8. Most overburden and soil between waste zones is not contaminated above preliminary remediation goals and therefore will not require remediation. Cost estimates and evaluations for retrieval and ex situ treatment alternatives will be based on the volume defined by multiplying the combined areas of waste zones by the average depth to basalt excluding the clean overburden. Waste volumes will be defined by available inventory data. Contaminated soil volumes will be defined as all interstitial soil within a waste unit plus an additional 0.3 m (1 ft) of soil from the underburden and overburden to account for potential contaminant migration and uncertainty in waste area dimensions.

9. Cost estimates and evaluations of in situ treatment alternatives will be based on the combined areas of the waste zones and the average depth to basalt including the overburden.

10. The PERA will address the total waste unit volume estimates as the WAG 7 ABRA (see Table 3-1).

11. Some of the drums buried in the SDA contain freestanding, potentially flammable liquid.

12. Active low-level waste disposal operations at the SDA will continue until 2020. Any alternative evaluated in the PERA will incorporate measures to accommodate ongoing operations.

13. Any waste retrieved from the SDA containing transuranics in concentrations greater than 100 nCi/g will be shipped to WIPP.

14. Treatment residuals for OU 7-13/14 can be disposed of onsite that have less than 100 nCi/g transuranic waste (TRU) and meet RCRA (42 USC § 6901 et seq.) land disposal restrictions (LDRs) and all risk-based levels established in the OU 7-13/14 ROD.

15. Final closure of ongoing disposal operations (i.e., Pits 17 through 20 including the engineered soil vaults) will be evaluated and implemented under CERCLA as a component of the OU 7-13/14 remedial action.

16. Remedial alternatives evaluated in the PERA for addressing contaminated soil within the SDA are sufficient to address potentially contaminated soil within TSA.

2.3 Project Environmental Standards

Remediation alternatives developed in later sections of this WAG 7 PERA include technologies that treat, contain, or isolate waste to prevent biotic exposures and minimize future contaminant releases to adjacent media. To assess a remedial alternative's ability to provide long-term protection of human health and the environment, preliminary standards and limits must be established to identify ARARs and PRGs that address identified COCs.

2.3.1 Regulatory Status

Developing and evaluating remedial action alternatives for WAG 7 require understanding regulations that govern current RWMC operations and future remediation. Because of the continuing evolution of environmental regulations, managing waste within the RWMC has been subject to varying requirements over time. Currently, both RCRA and CERCLA remedial authority apply, as do DOE directives and orders, with RCRA applied to permitted areas within the active TSA facilities and CERCLA generally applied to areas contaminated by past practices. The PERA presented in this report does not address active operations or facilities currently operating within WAG 7. However, closure of the TSA and the active low-level waste (LLW) disposal operation in Pits 17 through 20 in the SDA will ultimately be incorporated into the final closure for the RWMC under CERCLA.

2.3.2 Applicable or Relevant and Appropriate Requirements

Applicable or relevant and appropriate requirements are regulations that influence the selection and implementation of a remedial action. Such requirements may be either *applicable* or *relevant and appropriate*, but not both. As promulgated under federal or state law, *applicable* requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that specifically address a hazardous substance, remedial action, location, or other circumstance at a site. *Relevant and appropriate* requirements are those cleanup standards; standards of control; and other substantive environmental protection requirements, criteria, or limitations that address problems and situations sufficiently similar to those encountered at the site that their use is well-suited to the particular circumstance.

A requirement of CERCLA Section 121(d)(2)(A) is that remedial actions comply with federal, state, and tribal government ARARs. To be regarded as ARARs, state and tribal requirements must meet the following three criteria:

- Be a promulgated standard, requirement, criterion, or limitation under a state environmental or facility siting law
- Be more stringent than federal requirements
- Meet the definition of an ARAR (i.e., be either legally applicable or relevant and appropriate).

The ARARs identified by the feasibility study process serve only as screening criteria for evaluating alternatives—the final project ARARs will be identified in the future OU 7-13/14 ROD. The feasibility study process identifies only potential ARARs that protect human health and the environment during and following implementation of a given remedial action. The WAG 7 feasibility study evaluation determines whether a specific alternative can satisfy the potential ARARs while achieving the RAOs.

The ARAR analyses provided in this report compare numerous site-specific factors, including particulars of the remedial action, hazardous substances of concern at the site, and physical characteristics of the site, to those addressed in statutes and regulations. When ARAR analysis indicates that a requirement is applicable or relevant and appropriate, the requirement must be met or must satisfy specific statutory requirements in order to be waived. The ARAR analysis (provided in Appendix A) includes promulgated environmental requirements, criteria, standards, and other limitations, and presents potential WAG 7 ARARs in terms of three primary categories:

- Chemical-specific ARARs—These generally establish media-specific (air, soil, groundwater, and surface water) concentration limits or discharge limitations for specific chemicals. When an individual chemical is subject to more than one limitation, the more stringent requirement is typically used.
- Location-specific ARARs—These relate to geographical or physical position of the site, limit types of remedial action that can be implemented, or may impose additional constraints on some remedial alternatives.
- Action-specific ARARs—These generally establish performance, design, or other similar action-specific controls or restrictions on particular activities, and are activated by specific remedial actions selected to accomplish a remedy. The action-specific requirements themselves do not determine remedial alternatives, but indicate how or to what level selected alternatives must perform.

Other factors in selecting a remedy, designated as "to be considered" (TBCs), might include unpromulgated standards, criteria, advisories, or specific DOE orders. However, TBCs are neither legally binding nor evaluated using the formal process required for ARARs.

2.3.3 Contaminants of Interest

The ABRA (Holdren et al. 2002) identified human health and ecological COCs for buried waste within the SDA. A total of 16 human health COCs were identified that exceeded either a 1E-05 carcinogenic risk or contributed to a cumulative noncarcinogenic hazard index of 2 or more. As shown in Table 1-1, the exposure pathway that contained the majority of the COCs and exhibited the highest degree of risk was groundwater ingestion. Other pathways that exhibit unacceptable risks from one or more of the COCs include soil ingestion, inhalation, external exposure, and crop ingestion from surface uptake. The ABRA also identified seven ecological COCs (See Table 1-2), based on a hazard quotient of 1 for radionuclides and 10 for nonradionuclides. The primary pathways of ecological concern were associated with burrowing animals and insects and plant ingestion.

Remedial alternatives presented in this PERA are designed to achieve the RAOs by applying specific technologies to treat, isolate, immobilize, or remove waste streams containing the COCs. Technologies mitigate risks by directly treating COC-bearing waste or by inhibiting potential exposure pathways.

2.3.3.1 Cover Placement. After remedial measures are completed, all the alternatives presented in this PERA (with the exception of the No Action alternative) include employing institutional controls and placing a cover over the SDA to preclude direct access to any waste or areas of contamination (DOE-ID 1998). Placement of this cover would mitigate a number of exposure pathways identified in the ABRA as contributing to human health risk. Properly designed covers would mitigate human health COC risks associated with soil ingestion, inhalation, external exposure, and crop ingestion. Cover systems would also mitigate ecological COC risks related to vegetation uptake and burrowing animals and insects. It is assumed in this PERA that additional measures to address the COC risk associated with these pathways will not be necessary. Therefore, COC waste that exhibits ecological risks only, such as lead and cadmium, will not be targeted for additional remedial measures. Further, waste that poses risk only via soil ingestion, inhalation, crop ingestion, or external exposure will not be targeted for additional remedial measures. Alternatives assembled in subsequent sections of this PERA are, therefore, primarily focused on developing methods to mitigate contaminant migration that may affect groundwater exposure pathways.

2.3.3.2 Protection of Groundwater. Development and analysis of remedial action alternatives, presented in following sections, focus on remediating the source term waste, through either containment, in situ treatment, or retrieval, as required to address risks identified in the ABRA (Holdren et al. 2002) associated with the groundwater ingestion pathway. The COCs identified for this pathway are listed below.

- C-14
- I-129
- Np-237 (and parent Am-241)
- Tc-99
- U-233, U-234, U-235, U-236, U-238
- Carbon tetrachloride
- Methylene chloride
- Nitrates
- Tetrachloroethylene.

In addition to risk-based COCs listed above, Am-241 and three plutonium isotopes are groundwater COCs. Though Am-241 also was not a direct COC for groundwater ingestion, the majority of Np-237 is created through Am-241 decay. The three plutonium isotopes, Pu-238, Pu-239, and Pu-240, were classified as special case groundwater COCs to acknowledge uncertainties about plutonium mobility in the environment and to reassure stakeholders that risk management decisions for the SDA will be fully protective (Holdren et al. 2002). Because most plutonium in the SDA is collocated with risk-based COCs that have similar properties, treating plutonium isotopes as COCs will have little effect on analysis of alternatives or on risk management decisions.

Based on disposal records, the COCs are concentrated in several waste forms. A discussion of waste forms along with their distribution within the SDA is presented in the following subsections.

2.3.3.2.1 Actinides—Based upon results of fate and transport modeling conducted for the ABRA, actinide COCs were identified as representing the greatest long-term risks to area groundwater. As shown in Table 1-1, peak cumulative groundwater risk, occurring approximately in 3110, is primarily attributable to uranium and Np-237. Risk attributed to Np-237 is 4E-04, while risks attributed to uranium isotopes range up to 3E-03 for U-238.

Actinide COCs include Am-241, U-233, U-234, U-235, U-236, U-238, Pu-238, Pu-239, Pu-240, and Np-237. The majority of the long-lived, relatively immobile actinides are contained within the RFP sludge deposited in drums within the pits, Pad A, and Trenches 1 through 10. Distribution of actinide waste in the SDA is depicted in Figure 2-2.

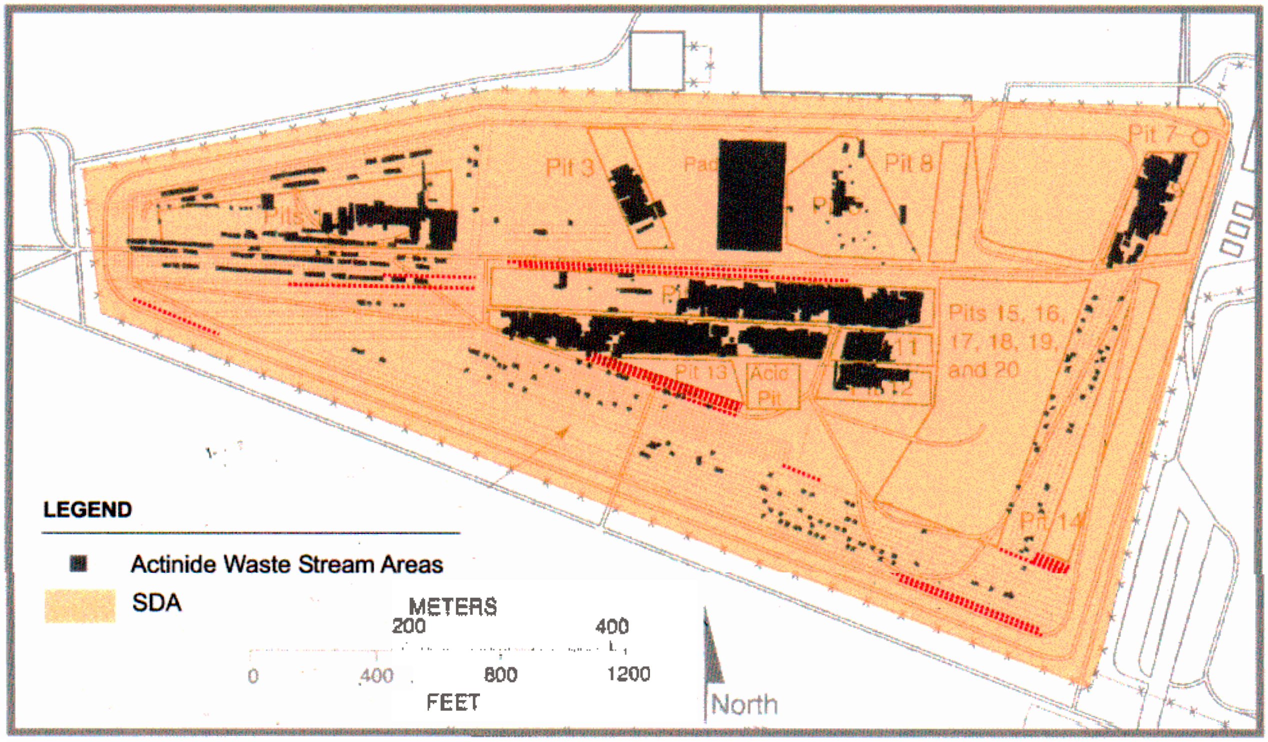


Figure 2-2. Actinide waste distribution in the Subsurface Disposal Area.

2.3.3.2.2 Activation and Fission Products**—**As shown in the ABRA, mobile long-lived fission and activation products constitute a significant contribution to near-term risk. As shown in Table 1-1, peak near-term groundwater risk in 2110 is primarily attributable to C-14, I-129, and Tc-99.

Activation product waste streams include C-14, Nb-94, and Tc-99, and fission product waste streams include I-129. Both waste streams were generated primarily from INEEL reactor operations and consist mainly of metal and scrap metal pieces, core loop components, core structural pieces, resins, and irradiated fuel material. Waste was buried in various container types, primarily in the trenches and as remote-handled waste in the SVRs. Distribution of waste is depicted in Figure 2-3.

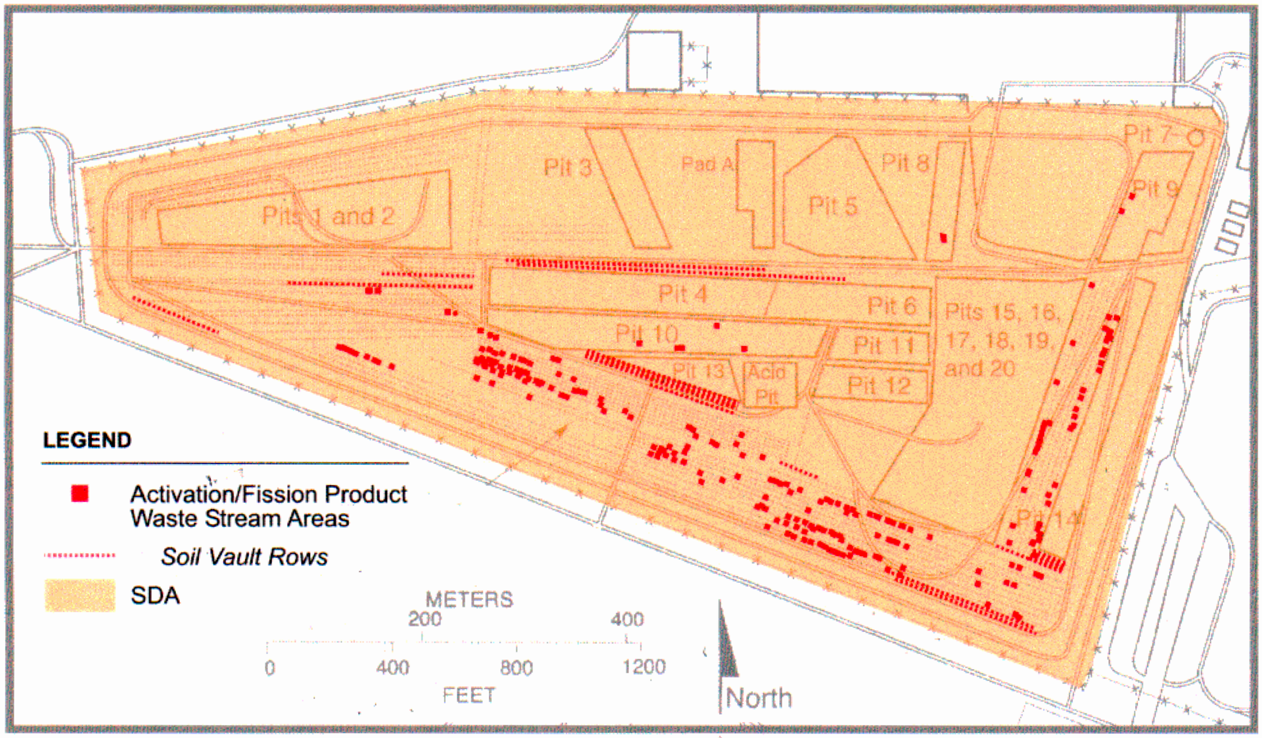


Figure 2-3. Activation and fission waste distribution in the Subsurface Disposal Area.

2.3.3.2.3 Volatile Organic Compounds—Volatile organic compound COCs include carbon tetrachloride (CCl_4), tetrachlorethylene (PCE), and methlyene chloride. Carbon tetrachloride, which was identified in the ABRA as the contaminant potentially posing the most imminent groundwater risk, has been previously detected in the underlying aquifer at concentrations slightly above drinking water standards and is being actively extracted from the vadose zone beneath the SDA. As shown in Table 1-1, the projected peak risks for CCl_4 occur in 2105 with a carcinogenic risk of 2E-03 and a hazard index of 50.

Almost all CCL_4 and PCE are contained in the bagged and drummed organic sludge (Series 743 Sludge) from the RFP. Methylene chloride is also contained almost entirely in the RFP waste streams consisting of sludge, paper, rags, plastic, equipment, and assorted debris. Distribution of VOC waste within the SDA is presented on Figure 2-4. As is shown, waste streams are primarily located in Pits 1 through 6 and 9 through 12 and Trenches 1 through 10.

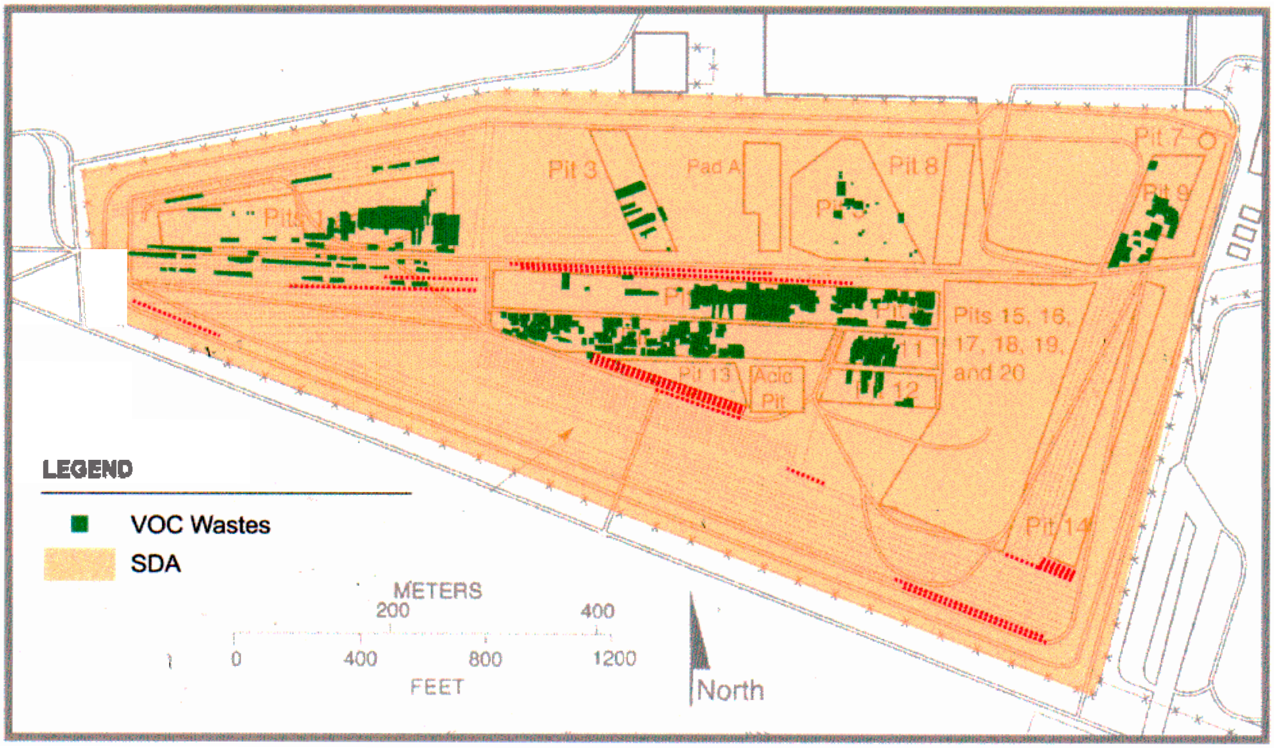


Figure 2-4. Volatile organic compound waste distribution in the Subsurface Disposal Area.

2.3.3.2.4 Nitrates—Nitrate was identified in the ABRA as a groundwater COC with a projected hazard index at the threshold value of 1.0 occurring in 2120. Nitrates within the SDA are located almost entirely in the drummed waste stream (Series 745 Sludge) shipped from the RFP between 1967 and 1970. Nitrate waste in the SDA is located within Pad A, and Pits 4, 6, 9, 10 and 11 as shown on Figure 2-5.

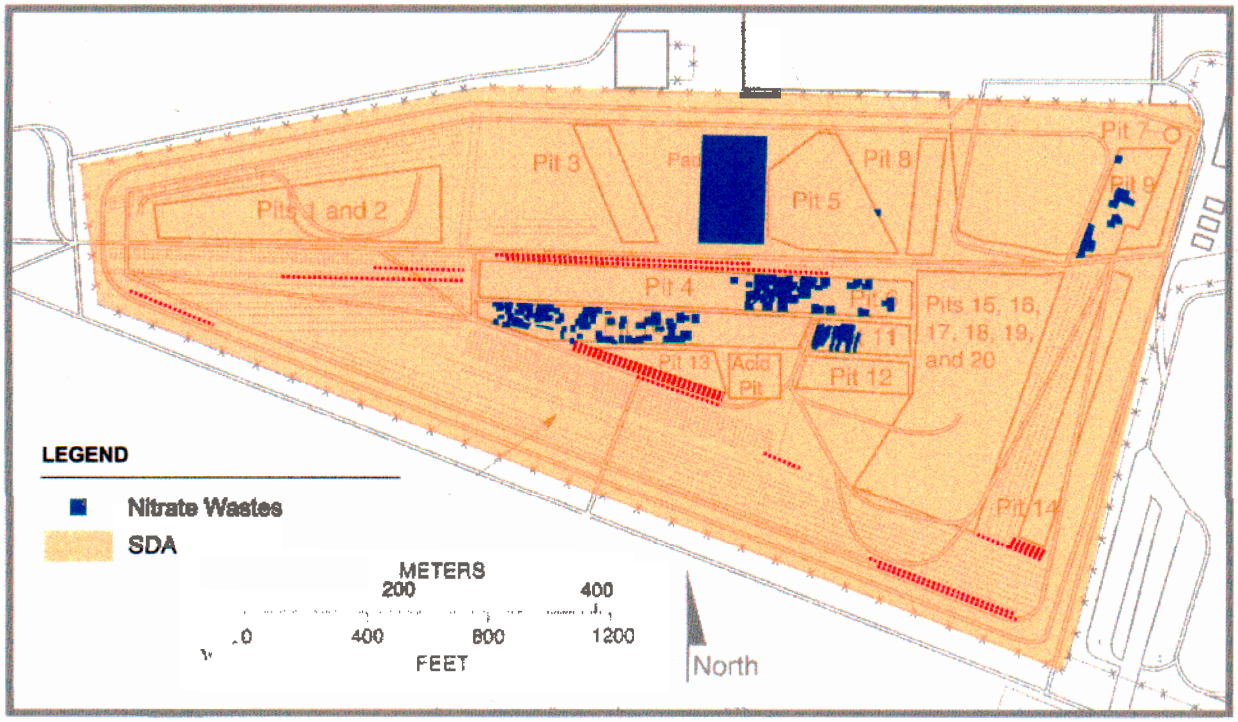


Figure 2-5. Nitrate waste distribution in the Subsurface Disposal Area.

2.3.4 Preliminary Remediation Goals

A PRG is a risk-based goal that is based on available site information. Specifically, PRGs focus on protecting human health and the environment and are therefore statements of desired endpoint concentrations or risk levels that provide adequate protection. In accordance with NCP guidance (40 CFR 300), PRGs are generated from readily available toxicity and exposure factor information (including contaminants, media, and pathways), reasonable exposure assumptions, frequently used standards (e.g., ARARs), and probable future land use. For probable future land use for parts of the INEEL site, including WAG 7, this analysis assumes continuing government control and ownership in perpetuity. Further, it is assumed that future residential development may occur within current INEEL boundaries and immediately adjacent to the RWMC, but not within the RWMC. Therefore, a residential scenario for possible exposure should be assumed for identifying PRG risks in the WAG 7 feasibility study. Final remediation levels, which are determined when a remedy is selected, will be presented in the future ROD.

In the feasibility study process, PRGs are used to quantify the extent of a remedial action that would be required to achieve the project RAOs. The ABRA concluded that the media of primary concern for future risk associated with the SDA are contaminated soil and groundwater. However, as discussed in Section 1.1, this PERA and the WAG 7 feasibility study will focus on remedial alternatives that mitigate release of contamination from the source term only. Therefore, technology applications for remediating area groundwater are not directly addressed. To protect future groundwater impacts, this PERA evaluates measures to control the source term through specific technology applications that contain or treat COC-bearing waste streams within the SDA and inhibit contaminant migration to the aquifer.

The source term is defined by dimensions of waste disposal units and contaminated soil extending down to the upper basalt zone interface. The volume of contaminated soil and waste requiring remediation is estimated based on historical records and available inventory data that define the volume and extent of COC-bearing waste streams.

Remedial alternatives are designed to protect groundwater through controlling future releases of contaminants from the source term. For the WAG 7 feasibility study, the effectiveness of a remedial action will be evaluated based on ability to achieve an acceptable release rate for each of the groundwater COCs, as required to meet groundwater quality standards and to protect human health and the environment. Developing contaminant-specific release rates was not within the scope of this PERA.

2.4 General Response Actions

Defined as general approaches that can be implemented to achieve RAOs, GRAs encompass a broad range of activities, including institutional controls, containment, in situ treatment, retrieval, ex situ treatment, and disposal. In some cases, multiple GRAs can be combined to form an individual assembled alternative (e.g., an alternative that retrieves, ex situ treats, and disposes of contaminated soil and waste).

The GRAs for WAG 7 are discussed briefly in following sections. Each GRA is defined by a number of specific remedial technologies and process options. Remedial technologies are methods for resolving specific technical problems within the GRA approach. For example, a GRA of containment could be accomplished with various remedial technologies: a surface barrier, surface controls, or subsurface horizontal and lateral barriers. In turn, process options are specific techniques that achieve the selected remedial technology. For example, the remedial technology of lateral barriers consists of a number of process options: slurry walls, grout curtains, sheet piles, or in situ soil vitrification.

2.4.1 No Action

The No Action GRA serves as a base comparison for other remedial actions and involves no specific technologies to treat, stabilize, or retrieve site contaminants, or to reduce potential exposure pathways with methods such as fencing or administrative controls.

2.4.2 Institutional Controls

The Institutional Controls GRA imposes physical or regulatory restrictions to prevent or limit access to contaminated areas for as long as DOE or another government agency owns the INEEL. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," which states that DOE must maintain control of the site for as long as the waste left after remediation remains hazardous, would necessitate implementing administrative procedures, deed restrictions, fences or other barriers, signs, and security until the site could be released for unrestricted use. Monitoring is also a technology within the Institutional Controls GRA and is used as an element in all the alternatives (including No Action) to evaluate future environmental conditions.

2.4.3 Containment

The Containment GRA mitigates risks posed by chemical and radiological contaminants at the site by constructing physical barriers that prevent direct human and biotic contact and minimize and control contaminant migration to groundwater, surface water, or air. Specific containment technologies that potentially satisfy the WAG 7 RAOs include surface control or diversions, capping, lateral barriers, biotic barriers, and bottom sealing. Containment technologies prevent soil erosion, reduce infiltration of moisture that can transport contaminants to the groundwater, and eliminate surface exposure pathways.

2.4.4 In Situ Treatment

The In Situ Treatment GRA involves technologies that reduce risks posed by chemical and radiological contaminants while the waste remains in-place (in situ). Treatment technologies include physical, chemical, thermal, electrokinetic, and biological treatment to modify waste in-place and reduce contaminant mobility, toxicity, or volume by degradation, fixation, or destruction. In situ technologies are available that reduce mobility, toxicity, and volume of nonradiological waste and soil impacted by either inorganic or organic contaminants. However, no technology exists to destroy or reduce toxicity of radionuclides. Detailed discussions of two possible in situ treatments—in situ grouting (ISG) and in situ vitrification (ISV)—that address radionuclide mobility are presented in two reports prepared specifically for the PERA (Armstrong, Arrenholz, and Weidner 2002; Thomas and Treat 2002).

2.4.5 Retrieval

The Retrieval GRA involves physically removing overburden soil, interstitial soil, waste, and any impacted soil immediately beneath buried waste. Because of radioactive and hazardous characteristics of the SDA waste, retrieval systems that minimize worker exposure and maximize source control are required. Retrieval process options include traditional earth-moving equipment (e.g., backhoes, front-end loaders, and cranes), standard construction equipment with modifications, and remote techniques (e.g., robotics). A supporting report prepared for this analysis discusses potentially applicable retrieval process options and screening criteria in further detail (Sykes 2002).

2.4.6 Ex Situ Treatment

The Ex Situ Treatment GRA entails treating retrieved soil and waste via chemical, physical, thermal, electrokinetic, or biological technologies. The technologies focus on physical waste segregation (hazardous constituents versus nonhazardous), radiological segregation (e.g., TRU, LLW, and mixed low-level waste ([MLLW]), and processing to reduce toxicity, mobility, and volume of contaminants. The type of processing depends on governing requirements for specific waste, but could include sizing, treatment to remove or destroy organics, treatment to stabilize heavy metals, absorption of liquids, and repackaging. Depending on method of treatment, waste volume could either decrease or increase. For the assembled alternatives, treatment technologies evaluated for reducing mobility, toxicity, and volume are focused on retrieved MLLW, as required to meet specific regulatory requirements. Ex situ treatment for TRU waste and soil are focused primarily on segregation and sizing technologies to provide for off-Site disposal.

2.4.7 Disposal

The Disposal GRA involves the placement of retrieved waste and contaminated soil in on-Site and off-Site permanent waste management facilities to restrict contaminant mobility and mitigate exposure routes.

2.5 Remedial Technology Identification and Screening

In accordance with CERCLA feasibility study guidelines (EPA 1988), the preliminary technology screening evaluates effectiveness, implementability (technical and administrative), and relative cost of potentially applicable remedial technologies and process options that mitigate exposure risks associated with the WAG 7 COCs. Given the complexity of waste streams buried in the SDA, some uncertainties exist regarding the potential effectiveness, implementation, and cost of a specific technology or process option. Significant uncertainties are noted in the technology descriptions provided below and in the development and screening of alternatives presented in Sections 3 and 4.

A series of technical reports, as listed below, specifically support the PERA evaluations of effectiveness, implementability, and cost for a number of the process options.

- *Operable Unit 7-13/14 Evaluation of In Situ Grouting* (Armstrong, Arrenholz, and Weidner 2002)—The report focuses on applying ISG as a remediation technology for mixed radioactive waste landfills, evaluates the effectiveness and implementability of the technology, and summarizes previous applications of ISG.

- *Operable Unit 7-13/14 Evaluation of In Situ Vitrification* (Thomas and Treat 2002)—The report details potential ISV applicability to waste and conditions documented at the SDA and evaluates issues of effectiveness and implementability, previous applications, and data gaps associated with the technology.

- *Operable Unit 7-13/14 Evaluation of Soil and Buried Transuranic Waste Retrieval Technologies* (Sykes 2002)—The report presents soil and buried TRU waste retrieval alternatives applicable to the SDA and identifies issues at the SDA, including effectiveness, implementability, and cost of retrieval actions.

- *Operable Unit 7-13/14 Evaluation of Short-Term Risks* (Schofield 2002)—The report assesses the short-term effectiveness of each alternative in protecting human health and the environment during preconstruction, construction, operation, and deactivation, decontamination, and decommissioning (D&D&D) phases until response objectives have been met.

Evaluation of effectiveness assesses the ability of each technology or process option to remediate waste media and meet RAOs. Specific assessments include:

- Ability of the technology to handle the types and volumes of contaminated media

- Reliability of the technology relative to contaminants and conditions at the sites

- Potential impact on human health and the environment resulting from implementing the technology.

Evaluating implementability assesses technical and administrative aspects of each technology. *Technical* implementability refers to technology-specific parameters that constrain effective construction and operation of the technology relative to site-specific conditions. *Administrative* implementability refers to the success in obtaining required permits for on-Site and off-Site actions, the availability of treatment, storage, and disposal services; the availability of equipment and personnel required for implementing the technology; and the ability to meet ES&H requirements.

Considerations of cost include relative estimates of capital and operation and maintenance costs. Engineering judgment is used to gauge costs as high, moderate, or low relative to other process options in the same technology.

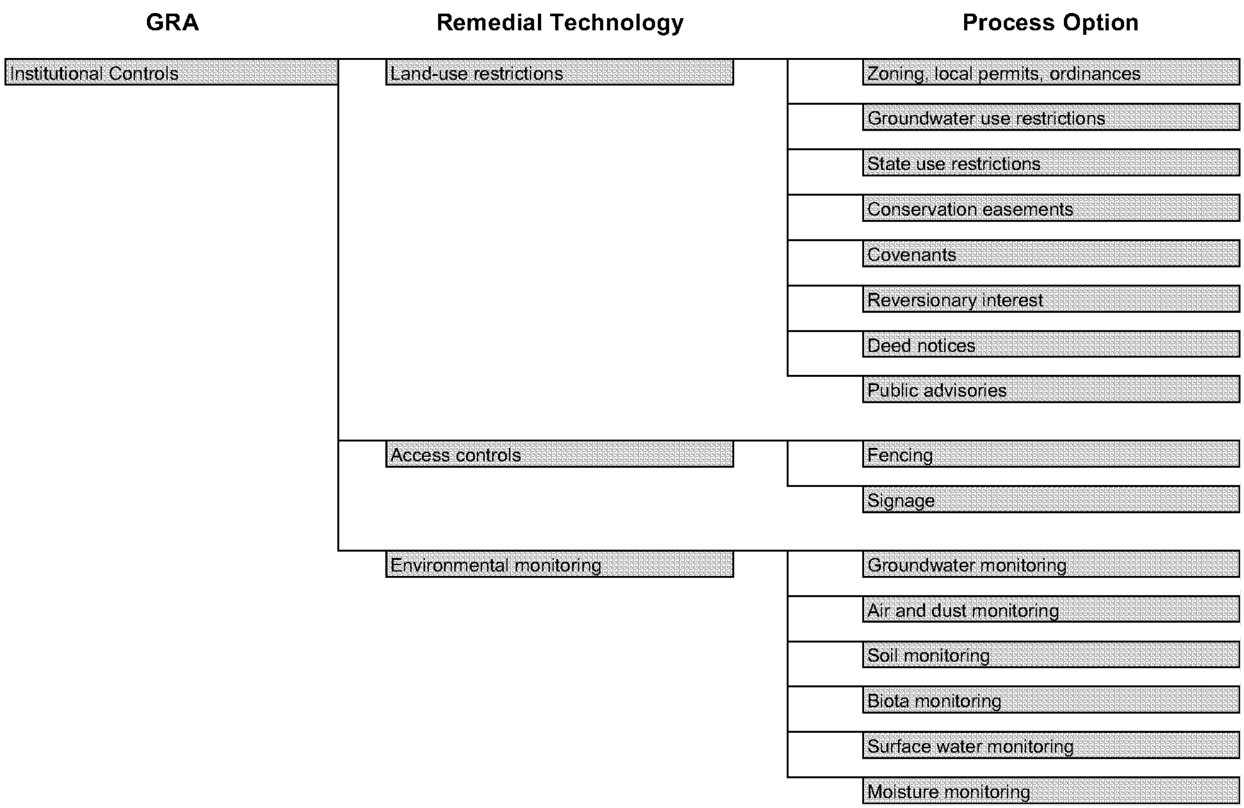
Remedial technologies and process options identified for each GRA, along with results of the screening evaluations, are described in following sections and summarized in Appendix B. Following sections also identify representative process options and designs for a technology or GRA, where applicable.

2.5.1 No Action

No specific technologies directly relate to the No Action GRA. However, EPA guidance for developing an RI/FS indicates that monitoring is an appropriate element in a No Action alternative (EPA 1988). Therefore, an environmental monitoring component has been included in the No Action alternative presented in Sections 3 and 4.

2.5.2 Institutional Controls

Three basic remedial technologies were evaluated for the Institutional Controls GRA: land-use restrictions, access controls, and environmental monitoring. Process options associated with each technology are presented on Figure 2-6. Descriptions and results of preliminary screening for each of the remedial technologies are presented in following subsections.



NOTE: Shading indicates technologies and process options retained for evaluation.

Figure 2-6. Institutional controls screening summary.

2.5.2.1 Land-Use Restrictions. Future land use at the site could be controlled with a number of projected process options. Measures that DOE could use to implement long-term stewardship of the SDA involve various options:

- Zoning, local permits, ordinances—Primary vehicles used by local governments to control land use. Zoning regulations are not necessarily permanent because they can be repealed or local governments can obtain exemptions after public hearings. In addition, zoning regulations might not be fully effective unless monitored and enforced.

- Groundwater-use restrictions—Restrictions include limitations or restrictions on well drilling in the affected area or buffer zone. Local governments could impose such restrictions to limit or prohibit certain uses of groundwater.

- State-use restrictions—State statutes could be imposed that authorize DOE to establish use restrictions specifically for contaminated property. Such statutes would override common law impediments to allow long-term enforceability of the property interests. The state or the federal government may shoulder the role for enforcement.

- Conservation (positive and negative) easements—State statutes could be imposed to establish easements to conserve and protect the property and limit future construction activities. Positive easements could be imposed to allow monitoring access. Negative easements could be imposed to prohibit drilling or other activity.

- Covenants—An agreement could be made upon conveyance of the property to use or refrain from using the property in a certain manner.

- Reversionary interest—A clause could be placed in a deed specifying that the property would revert to the original owner under certain conditions. Such a clause might further place conditions on the transferee's right to own and occupy the property and could be binding upon any subsequent purchasers.

- Deed notices—A deed notice commonly refers to a nonenforceable, purely informational document filed in public land records that alerts anyone researching records to information about the property. Notices could discourage inappropriate land use, but would have little or no effect on a property owner's legal rights concerning the property.

- Public advisories—Public advisories could be issued by public health agencies at federal, state, or local levels warning potential users of the land, surface water, or groundwater of existing or impending risk associated with that use. Such advisories have no legal or enforceable effects, but might reduce certain uses of a site and could provide information to the public.

All land-use restriction measures discussed above have been retained as potential components of a remedial action alternative. The identified measures can be used in combination with other action-specific technologies to prevent compromising associated site controls, minimize future maintenance requirements, and provide control for potential exposure pathways that might result in an unacceptable risk to human health. Notably, however, the measures focus on controlling human access to the site and do not address potential ecological exposures.

2.5.2.2 Access Controls. Process options associated with Access Control technology include fencing and signage to reduce risks to human health by inhibiting exposure to contaminants in the SDA. Fencing involves enclosing individual or contiguous areas inside a fence with a locking gate. Signage offers posted warnings that inform potential intruders of site dangers. Process options primarily focus on potential human intruders, but also could be effective in limiting exposure to some animals. Fencing and signage are viable technologies for surface contamination that is neither a groundwater exposure risk nor likely to become airborne if undisturbed.

Access controls have been retained for assembly into potential remedial alternatives. Both fencing and signage are easily implemented and can be combined with other remedial actions to add an additional degree of protectiveness and minimize future damage associated with site intrusions.

2.5.2.3 Environmental Monitoring. Monitoring of potentially affected environmental media could be used to evaluate the effectiveness of an alternative in achieving RAOs. Environmental monitoring can include a number of process options:

- Groundwater monitoring—Groundwater monitoring could be performed to assess the effectiveness of remedial measures in inhibiting contaminant migration to the aquifer.

- Air monitoring—Air monitoring could include using high- and low-volume air samplers to determine if fugitive radionuclides escape sites where contaminated surface soil exists.

- Soil monitoring—Soil monitoring could include radiation surveys over and around sites where contaminated soil and debris are left in-place to determine whether radionuclides have been transported to the surface by plants or animals.

- Biotic sampling—Animal tissue could be analyzed for bioaccumulation of COCs. Vegetation also could be analyzed to evaluate contaminant uptake.

- Surface water monitoring—Surface water sampling could be performed to monitor effectiveness of remediation during runoff events.

- Moisture monitoring—Monitoring perched water and soil moisture within the vadose zone could be used to provide an early warning of infiltration and contaminant migration. Moisture monitoring in surface barriers and underlying vadose-zone soil could be performed to assess effectiveness of remedial measures.

Environmental monitoring provides for future assessment of environmental conditions and evaluation of the effectiveness of action-specific remedial alternatives, and has been retained for potential incorporation into the proposed remedial alternatives.

2.5.3 Containment

Containment technologies focus on constructing physical barriers to prevent direct contact with site contaminants and to minimize future contaminant migration. Technologies and process options for the containment GRA are divided into four areas:

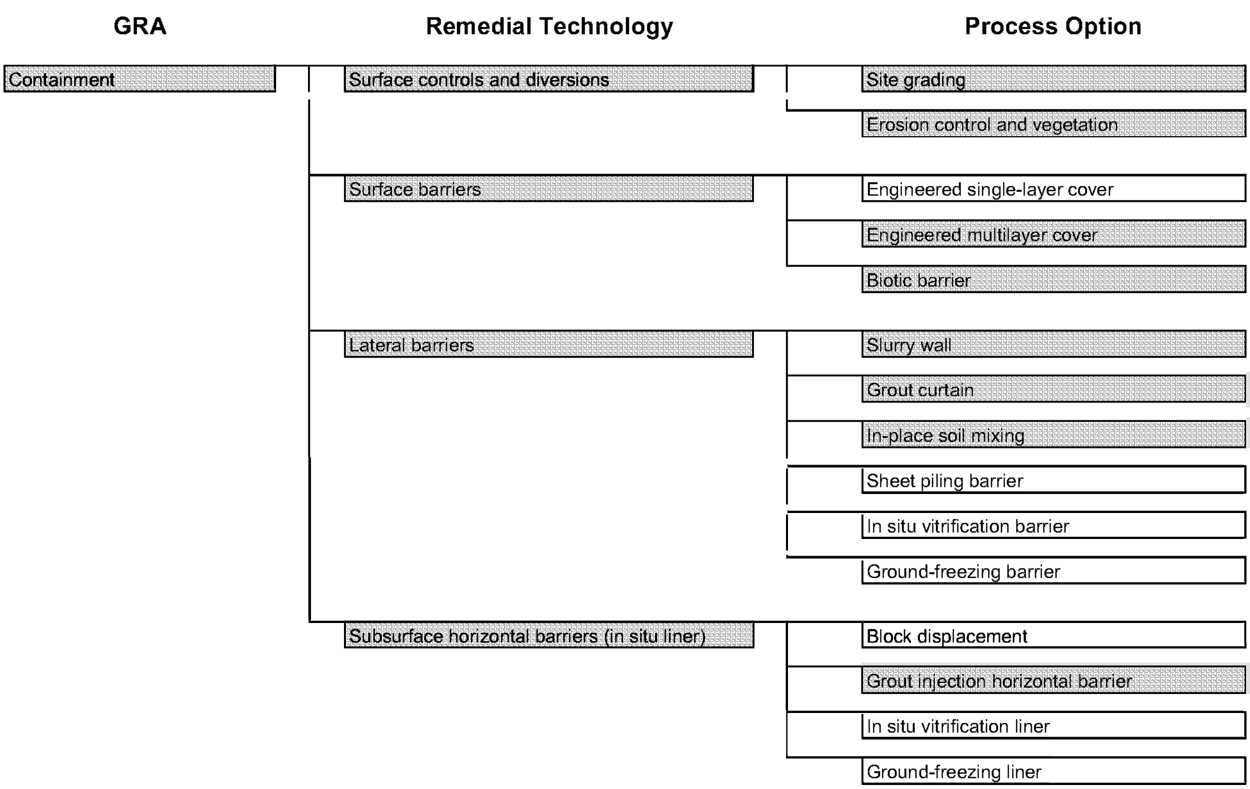
- Surface controls and diversions—Include measures to control surface water and minimize effects of erosion

- Surface barriers—Include measures to minimize surface water infiltration and inhibit biotic intrusion

- Lateral barriers—Include measures to control the lateral movement of moisture

- Horizontal barriers—Include measures to minimize the vertical movement of leachate from the source term.

Evaluated process options and screening related to effectiveness, implementability, and costs are presented in Appendix B. Figure 2-7 presents a summary of the screening. Descriptions and results of preliminary screening for each of the remedial technologies are presented below.



NOTE: Shading indicates technologies and process options retained for evaluation.

Figure 2-7. Containment technologies screening summary.

2.5.3.1 Surface Controls and Diversions. Surface controls and diversion consist of two process options—site grading and erosion control. The site grading process option would contour the ground surface of the SDA or individual disposal pits, trenches, and soil vaults to route water away from waste zones to reduce infiltration. Required slope of the contoured surface would depend on a number of factors including gradational characteristics of surface materials, nature of surface vegetation, and potential for future foundation subsidence. Site grading also could entail creating drainage swales or berms to control surface water flow. Drainage swales in combination with surface grading could be used to route surface water away from the SDA. Berms around the perimeter of the SDA could be used to prevent surface water run-on from adjacent areas.

Erosion-control measures include a physical cover to protect the soil from mobilization by precipitation and wind. Vegetation could function as erosion control and also provide physical cover. Vegetation generates transpiration, which removes water from the surface to a relatively shallow depth and reduces infiltration of surface water. A vegetated surface, if properly designed, is self-sustaining and long-lasting within a given climatic zone. Rock surfacing could also offer a means to minimize erosion from surface water runoff or wind, but may enhance infiltration.

Both the site-grading and erosion-control process options have been retained for developing remedial alternatives. Surface controls and diversions are essential to successfully implement any of the surface-barrier technologies discussed below.

2.5.3.2 Surface Barriers. Surface-barrier technology focuses on minimizing surface water infiltration into the waste, providing a biotic barrier to inhibit direct contact and intrusions by plants and animals, and inhibiting inadvertent human intrusion. As discussed previously in this PERA, the required construction of a surface barrier within the SDA is a basic assumption of the ABRA and has been incorporated as an element of all the alternatives (with the exception of No Action) assembled and evaluated in Sections 3 and 4. Three surface barrier process options have been identified: engineered single-layer covers, engineered multilayer covers, and biotic barriers. Specific design options associated with the process options are discussed below.

2.5.3.2.1 Engineered Single-Layer Cover—Engineered single-layer cover systems consist of a designed thickness of a single material such as compacted fine-grained soil, asphalt, concrete, and geomembranes. A single-layer cover was not retained for assembly into the remedial alternatives as a stand-alone design because of concerns associated with long-term effectiveness (i.e., the ability to achieve project RAOs and meet ARARs) and the availability of multilayer long-term cover systems (discussed in the following subsection), which are specifically designed to minimize long-term maintenance requirements. Single-layer cover systems considered in this PERA include:

- Soil cover—A soil cover alone would be susceptible to erosion, subsidence, biotic intrusion, and desiccation cracking, which would affect its long-term effectiveness. However, a soil cover could be used as a temporary option to facilitate implementing specific remedial alternatives. For the long-term, a soil cover is not suitable as a stand-alone process option.

- Asphalt cover—Asphalt is a flexible cover that can be designed to control surface-water infiltration, but environmental forces will degrade its integrity over time, and thus the cover would require continuous long-term maintenance to ensure compliance with RAOs.

- Concrete cover—A concrete cover would inhibit biotic intrusion into the waste until it cracks. Because concrete is rigid and subject to cracking, it cannot achieve RAOs and thus is eliminated from consideration.

- Geomembrane cover—Geomembranes show limited effective lives when exposed to the environment and would, therefore, require periodic replacement.

Though not retained as standalone process options, the basic design elements of the single layer cover systems, as presented above (i.e., soil, concrete, asphalt, and geomembranes), have been retained for incorporation into the design of the engineered multilayer cover systems discussed in the following subsection.

2.5.3.2.2 Engineered Multilayer Cover—The designs for engineered multilayer cover process options involve using different rock, soil, and synthetic materials to control surface water infiltration and prevent biotic (animal and plant) intrusions. Designs also offer varying degrees of protectiveness to inhibit future human intrusion into the waste. Individual layers within the cover systems incorporate drainage and filter zones, capillary breaks, low-permeability (infiltration control) zones, biotic barriers, and gas collection zones. Four available designs representative of the technology are discussed below.

- Standard RCRA Subtitle C Cap—The standard RCRA Subtitle C cap is designed to provide containment and hydraulic protection for a performance period of 30 years (DOE-RL 1993). The surface barrier comprises five layers with a combined minimum thickness of 1.65 m (5.5 ft) and a vegetated erosion-control surface. Additional optional layers for gas venting or biointrusion may be added.

- Modified RCRA Subtitle C Cap—The modified RCRA Subtitle C cap is designed for long-term containment and hydraulic protection for a performance period of 500 years, including provisions to control biointrusion. The surface barrier is composed of seven layers with a combined minimum thickness of 1.7 m (5.6 ft) and a vegetated erosion-control surface. Layers include topsoil with or without pea gravel, sand filter, gravel filter, lateral drainage layer, asphalt, and base course over grading fill. The asphalt layer controls both drainage and biotic intrusion. An optional gravel layer can be included in the design to control future gas migration from the waste.

- Long-term composite cover—The design of the long-term composite cover provides long-term isolation for radiological waste sites at the Hanford, Washington, DOE site for a performance period of 1,000 years. The cover is composed of nine layers of durable material with a combined thickness of 4.5 m (15 ft) and a vegetated erosion-control surface. Layers include topsoil with or without pea gravel, sand filter, gravel filter, fractured basalt, lateral drainage, asphalt, and base course over grading fill. The 1.5-m (5-ft) layer of fractured basalt is designed to prevent biotic intrusion. The overall thickness of the cover system also inhibits human intrusion. An optional gravel layer can be included in the design to control future gas migration from the waste.

- Idaho National Engineering and Environmental Laboratory Site Composite Cover—The INEEL CERCLA Disposal Facility (ICDF) cover is designed to provide containment and hydraulic protection for a performance period of 1,000 years (Crouse 2002). The barrier is composed of nine layers with a combined thickness of 5.25 m (17.5 ft) and a vegetated erosion control surface. Layers include silt loam topsoil, sand and gravel filter layers, a cobble biointrusion layer, drainage gravel, a geomembrane, and compacted silt loam over a site-grading fill. The INEEL-specific design includes a 0.75 m (2.5 ft) layer of fractured basalt to prevent biotic intrusion. An optional gravel layer can be included in the design to control future gas migration from the waste.

Typical sections for each of the four designs are presented on Figure 2-8.

Engineered multilayer cover designs are all potentially implementable at the site. Preliminary borrow source evaluations indicate that suitable soil and rock construction materials are available either within the INEEL or from adjacent off-Site sources. A more detailed evaluation of suitability and volume of materials will have to be conducted. All identified cover systems would be effective in controlling surface water infiltration. The primary difference in potential effectiveness of the systems is projected design life.

The standard RCRA Subtitle C cap, with a projected design life of 30 years, represents a minimum requirement for hazardous waste landfills and is insufficient to address contamination within the SDA. Extensive maintenance and periodic replacement to address the project RAOs would be required. For this reason, the Standard Subtitle C cap was not retained for consideration in developing remedial alternatives at the site.

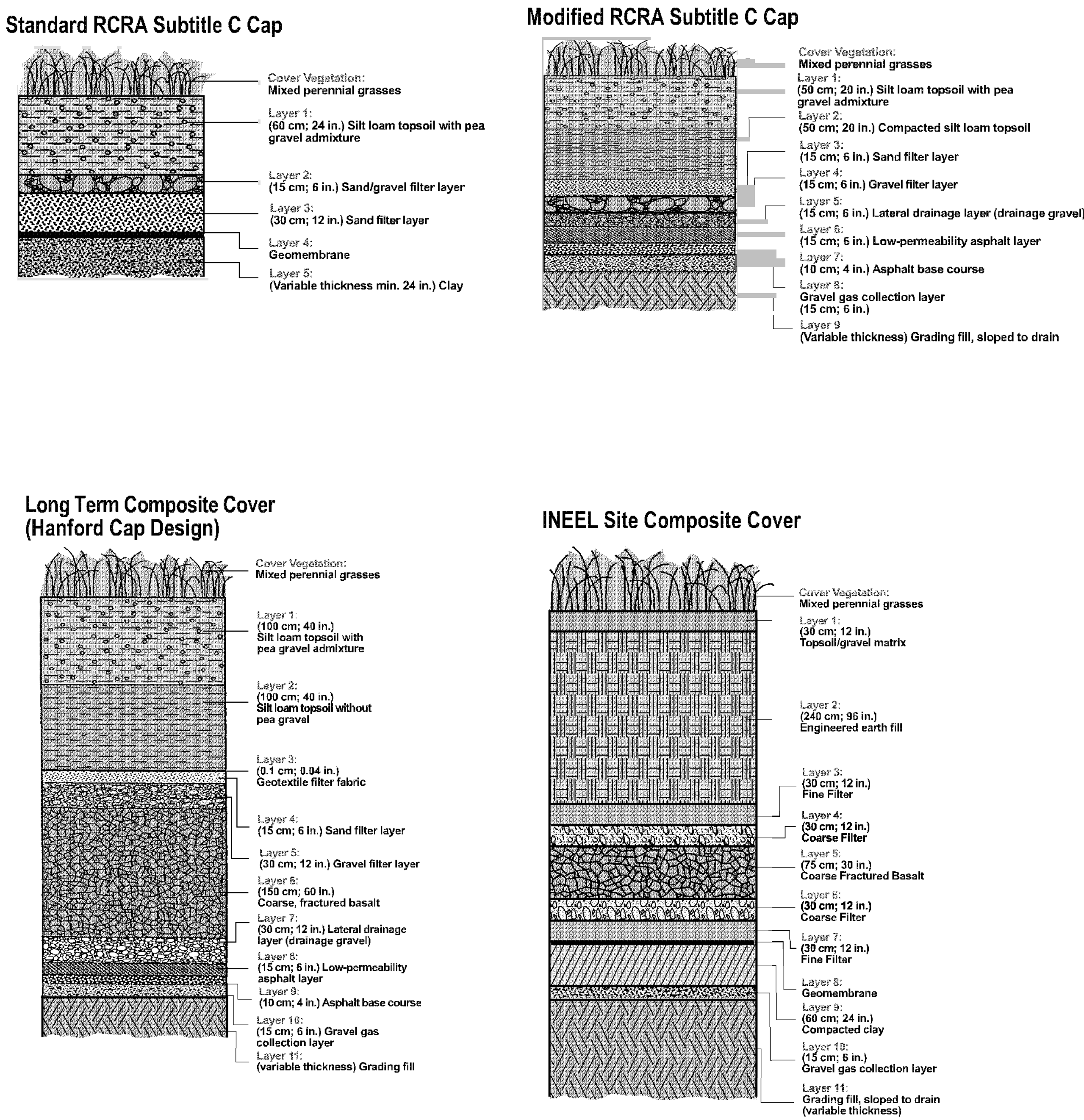


Figure 2-8. Engineered multilayer cover designs.

The modified RCRA Subtitle C cap provides an upgraded design life of 500 years that addresses long-term containment and the hydrologic protection requirements for sites containing LLW and MLLW. The upgraded design includes provisions to control biotic intrusion and incorporates RCRA minimum technology guidance with modifications for extended performance. One major change is elimination of the clay layer, which may desiccate and crack over time. The upgraded cap design (DOE-RL 1993) has been retained for consideration in developing remedial alternatives for the site. Its primary application will focus on alternatives that include either retrieval or in situ treatment for the LLW and MLLW components of buried waste. The cap will require periodic maintenance to ensure conformance with the RAOs with a full replacement every 500 years.

The long-term composite cover system was designed for the Hanford DOE facility to provide 1,000-year isolation of sites with greater-than-Class C waste, greater than Class C mixed waste, or significant inventories of TRU waste. The Hanford barrier is designed to provide the maximum available degree of containment and hydrologic protection. Evaluation of barrier needs for the national environmental restoration program identified the Hanford cover system as the baseline barrier design for cover alternatives at sites containing this type of waste. The ICDF cover system is a modification of the Hanford system designed to address site-specific environmental conditions and provide a 1,000-year design life. The ICDF cover system has been retained for consideration in developing remedial alternatives. Its primary application will focus on alternatives that involve TRU components of waste remaining in-place in an untreated state. The cap would require periodic maintenance to ensure conformance with the RAOs with a full replacement every 1,000 years.

2.5.3.2.3 Biotic Barrier—A biotic barrier is an engineered cover system designed to prevent direct contact with site contaminants and future intrusions into waste by plants and animals. Only one design, the Stationary Low-Power Reactor No. 1 (SL-1) Burial Ground cap, is evaluated. Designed for the INEEL WAG 5 Auxiliary Reactor Area, the SL-1 cap involves layers of basalt cobbles underlain and overlain by gravel, with a rock-armor surface designed to inhibit biotic intrusion. The design provides a total minimum thickness of 1.8 m (6 ft) to control surface exposures to radionuclides and inhibit biotic intrusion for approximately 400 years (INEEL 1996). A typical section depicting the biotic barrier design is presented in Figure 2-9.

The biotic barrier process option has been retained for assembly into remediation alternatives. The cover design will provide a degree of protection in restricting future biotic intrusions but increases surface water infiltration relative to undisturbed soil; any rainfall or snowmelt on the barrier rapidly moves through the depth of the very porous rock-armor and gravel-cobble layers beyond the depth of evaporation. The placement of SL-1 cap alone, therefore, would increase risk of future leaching of contaminants from the source term to underlying groundwater.

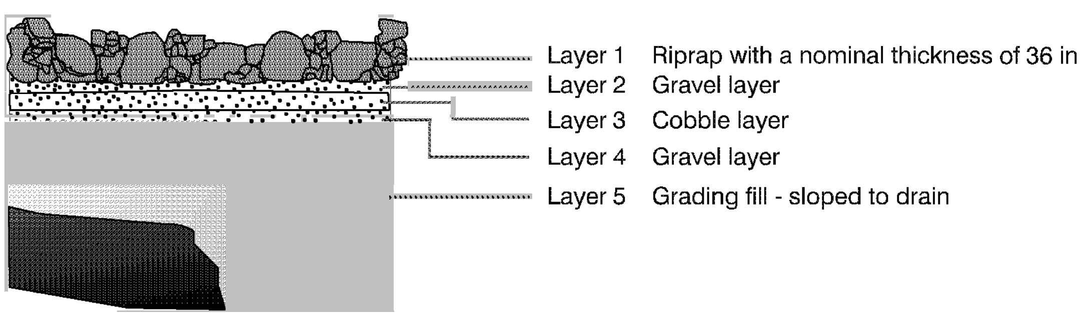


Figure 2-9. Biotic barrier (Stationary Low-Power Reactor No. 1 cap).

2.5.3.3 Lateral Barriers.

The lateral-barrier technology focuses on controlling lateral movement of moisture into and out of the SDA. Barriers would be constructed within the upper vadose zone soil extending from ground surface down to a design depth below bottom of waste zones, as required to control moisture movement. As shown in Figure 2-7, six basic process options for lateral barriers have been identified.

2.5.3.3.1 Slurry Walls—Slurry walls are a proven technology that can be readily implemented at the SDA with conventional earthwork equipment. Slurry walls are constructed by excavating a vertical trench around waste areas to a depth that is at or below bottom elevations of contaminated soil or waste materials. Trench stability is maintained by placing a liquid slurry of bentonite and water in the trench as excavation progresses. When the trench reaches the proposed maximum depth, the slurry is displaced from the bottom up with a dense barrier material consisting of soil bentonite, cement grout, polymers, plastic concrete, or other low-permeability materials. Using a continuous trenching construction method, cavities for slurry walls can be continuously excavated with a backhoe or excavator, filled with slurry, and backfilled with low-permeability material until waste disposal areas are completely encircled. Slurry walls can be excavated to depths of more than 30 m (100 ft) and can have a permeability as low as 1E-06 to 1E-07 cm/sec.

The slurry wall process option is implementable within the SDA and should provide an effective barrier to control lateral movement of water in upper vadose zone soil and underlying basalt. Conventional earthwork equipment, if properly sized, would be able to penetrate the near surface basalt layer and install the wall to the required design depth.

2.5.3.3.2 Soil Mixing—The in-place, soil-mixing process option uses multistemmed augers and mixing paddles to construct overlapping columns of soil mixed with cement, bentonite, or other admixtures. Soil columns are formed by pumping grout through hollow drill shafts and injecting grout into soil at the pilot bit. Grout is mixed with soil by the augers and mixing paddles as the augers are advanced. Once one series of columns is completed, additional columns are drilled using a specified overlapping pattern. The overlapping columns form a continuous wall of low-permeability material. Barriers are generally 0.5- to 0.9-m (1.5- to 3-ft) thick and can reach depths of more than 30 m (100 ft) depending on soil conditions.

A proven technology, soil mixing could be implemented at the SDA though overall costs are projected to be higher than costs for slurry wall technologies. Multiple auger systems have been designed to penetrate most geologic conditions, enabling this technology to achieve required design depths in the underlying basalt layer.

2.5.3.3.3 Grout Curtains—The grout curtain process option involves drilling around perimeters of waste disposal areas from ground surface to an elevation at or below bottoms of waste materials and injecting grout at high pressures (jet grouting) into each drill hole. A heavy duty, direct-push drill rig is used to advance casing to the specified depth. The casing tip is removed and grout is injected at discrete intervals from the bottom up as the casing is removed. Injection rates are carefully monitored to ensure that casings do not fill and that maximum dispersion of grout is achieved. A thrust block system would be required at ground surface to control grout flow. Intervals between grout injection holes would depend on hydrogeologic properties controlling dispersion of the grout. Multiple column layers form the wall or grout curtain.

While the grout injection process could be carefully monitored to achieve a minimum permeability and maximum continuity of the grout curtain, the ability to verify continuity at depth is difficult. Installation of the curtain would be further complicated by subsurface conditions and the irregular nature of the basalt soil interface. Lack of continuity in the grout curtain could substantially influence effective permeability.

2.5.3.3.4 Sheet Piling—Sheet-piling consists of constructing a vertical cutoff wall by driving vertical strips of steel, precast concrete, aluminum, or wood into the soil. Sheet-metal piling with sealable joints is commonly used. Interlocking sheets are assembled before installation and driven or vibrated into the ground a few feet at a time until the desired depth is achieved. Sheets are sealed by injecting grout in the joints between the metal sheet piles. Continuous sheet piling walls can potentially be driven to depths of 91 m (300 ft) in unconsolidated deposits lacking boulders. Bulk hydraulic conductivities of 1E-08 to 1E-10 cm/sec have been achieved in test cells constructed of joint sealed sheet pile.

Sheet piling is not applicable at the SDA because of the shallow, irregular nature of the upper basalt layer, which could preclude installation of the piling to required design depths. In addition, the cost for construction of sheet pile walls is high relative to the cost for other types of lateral barriers.

2.5.3.3.5 In Situ Vitrification—In situ vitrification, as described in Section 2.5.4.2, has been investigated for potential use as a lateral barrier but is not a proven technology for this application. Cost for constructing ISV barriers is high relative to costs for other types of lateral barriers.

2.5.3.3.6 Ground-Freezing —The ground-freezing process option involves drilling and installing rows of pipes to a specified depth around a waste containment area. Within each pipe, a smaller diameter feed pipe is installed, permitting circulation of cooling medium that freezes soil between the pipes. A large portable refrigeration plant would be needed to cool and circulate the brine. The ground-freezing system would operate continuously as a closed system requiring constant monitoring. Barrier thickness is 9 to 12 m (30 to 40 ft), with the depth limited only by well drilling capabilities.

Ground-freezing has been implemented as a containment technology and has the advantage of being able to be turned off if new requirements are necessary or new technologies become available. However, its application in shallow bedrock areas and the complex subsurface conditions of the SDA is questionable. In addition, ground-freezing has a high capital cost relative to the cost for other types of lateral barriers and has a high projected operation and maintenance cost.

2.5.3.3.7 Lateral Barrier Screening Summary—As a result of the screening process for the lateral barrier technology (summarized in Appendix B), slurry wall construction using continuous trenching has been identified as the representative process option. This technology is commonly used when installing shallow barrier walls and is well suited for variable subsurface conditions within the SDA. The grout curtain process option also has been retained for consideration in developing remedial alternatives, though slurry walls are preferred because of complex subsurface conditions and concerns over verifying the integrity of a grout curtain. The in-place soil mixing process option is also potentially implementable at the SDA, though implementation costs are projected to be higher than the preferred slurry wall option. Sheet-piling was not retained for consideration in developing remedial alternatives because of the shallow basalt layer and projected high relative capital cost. The ISV and the ground-freezing process options were not retained because of developmental issues and their high relative costs.

2.5.3.4 Subsurface Horizontal Barrier (In Situ Liner). Subsurface horizontal barriers control vertical movement of leachate from the source term. The technology involves constructing the barrier in situ (i.e., with the waste materials in-place). Four basic process options have been identified (see Figure 2-7) and are briefly summarized in the following sections.

2.5.3.4.1 Block Displacement—Block displacement involves vertically displacing a large mass of earth with a low permeability material. One construction technique is forming a horizontal barrier below the surface by pumping soil bentonite slurry into a gridded series of notched injection holes. To create a horizontal barrier, high-pressure air is pumped through a notching nozzle in the bottom of a borehole to displace mud and groundwater. Sand is injected through the nozzle to erode a radial notch around the base of the borehole. When the desired notch size is attained, slurry is pumped through the borehole until the notch and casing are filled, and additional slurry is pumped under low pressure to lift the soil. The subsurface barrier thickness constructed is generally 0.15 to 0.3 m (0.5 to 1 foot). Block displacement has been demonstrated only on a small scale, where subsurface conditions consist of uniform soil.

Implementing this technology at the SDA is questionable because of complex subsurface conditions (i.e., the shallow and irregular nature the upper basalt layer which immediately underlies waste) and the large size of individual disposal units.

2.5.3.4.2 Grout Injection—The grout injection horizontal barrier process option requires vertical drilling through the bottom of waste disposal areas within the SDA and grouting the underlying basalt layer. Grout would be injected into basalt through vertical boreholes drilled in a gridded pattern, with overlap, as required, to achieve horizontal continuity. The potential application of horizontal drilling and grouting could also be evaluated during final design of a barrier system. However, for this PERA, horizontal grout injection was not identified as a preferred approach because of the sizes of the waste units and the ability to maintain horizontal and vertical control of drilling and grout placement in fractured basalt.

2.5.3.4.3 In Situ Vitrification—A horizontal barrier beneath the waste could possibly be constructed. The construction technique would involve injecting the starter path at depth and beginning the melting process below the base of the waste. Though ISV has been investigated for potential use as a horizontal barrier, it is not a proven technology.

2.5.3.4.4 Ground-Freezing—A subsurface liner using ground-freezing would be constructed by drilling horizontally beneath waste disposal areas or vertically through the waste and installing cooling piping. As stated previously, ground-freezing has been implemented as a lateral containment technology, but has not been successfully implemented as a horizontal subsurface barrier. Disadvantages of ground-freezing include the difficulty and uncertainty involved with horizontal installation of coolant piping in subsurface basalt and high relative operational and maintenance costs.

2.5.3.4.5 Subsurface Lateral Barrier Screening Summary—Though concerns exist about the difficulty of verifying continuity of the barrier, grout injection has been identified as the representative process option for constructing a subsurface horizontal barrier. Block displacement was not retained for consideration in developing remedial alternatives because of compatibility issues associated with either basalt present at the base of many disposal areas within the SDA or the unconsolidated waste (buried drums, vaults, and voids) contained in the SDA. In situ vitrification is not a proven technology for this application and was not retained. Ground-freezing also was not retained because of high relative operation and maintenance costs and uncertainty concerning implementability and effectiveness in basalt.

2.5.4 In Situ Treatment

In situ technologies are used to reduce volume, mobility, or toxicity of waste in-place (in situ). A major advantage is eliminating material handling requirements and short-term risks associated with excavation, ex situ treatment, and subsequent disposal of contaminated soil and waste. Process options have been grouped under five basic technology categories:

- Physical treatment—Employs mechanical processes to either extract contaminants from affected media or immobilize contaminants through blending or injecting a fixating agent

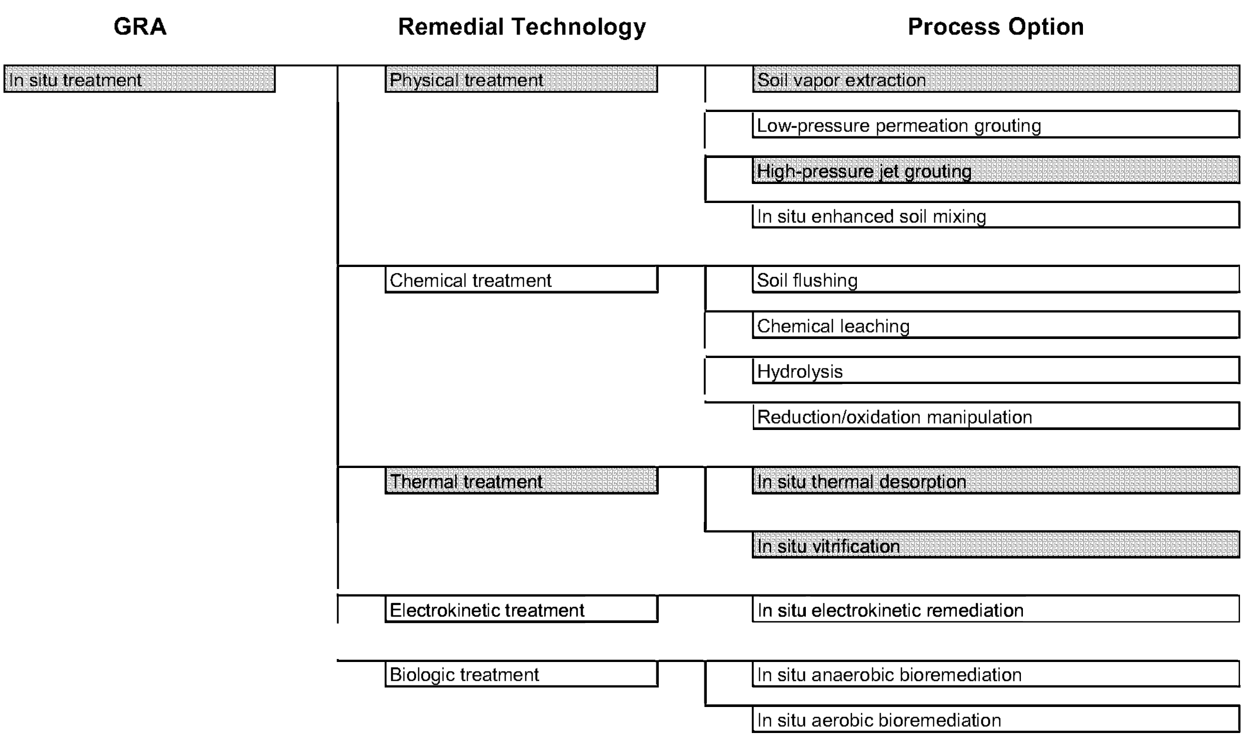
- Chemical treatment—Employs chemicals to either extract or degrade contaminants in affected media

- Thermal treatment—Employs heat to either extract or destroy contaminants in affected media

- Electrokinetic treatment—Employs electrical energy to extract contaminants from affected media

- Biologic treatment —Employs biological processes to degrade contaminants in affected media.

Process options evaluated for each in situ technology, along with specific screening comments related to effectiveness, implementability, and cost, are presented in Appendix B. A listing of the process options summarizing results of the screening evaluation is presented on Figure 2-10.



NOTE: Shading indicates technologies and process options retained for evaluation.

Figure 2-10. In situ treatment screening summary.

All process options for chemical, electrokinetic, and biologic treatment were eliminated during initial screening summarized in Appendix B. In situ chemical treatment includes four process options as shown on Figure 2-10. Soil leaching and chemical flushing were eliminated during the screening evaluation because of concerns associated with mobilizing contaminants and further impacting the underlying vadose zone and groundwater. Hydrolysis and reduction/oxidation manipulation were eliminated because of their experimental nature and unproven applicability to contaminants within the SDA. The electrokinetic technology is primarily effective in fine-grained soil and would not be applicable to buried waste in the SDA. Biological technologies could be effective on some organic waste; however, the technology is not applicable to containerized buried waste.

A total of four physical and thermal in situ treatment process options have been retained for developing remedial alternatives. Two of the retained in situ treatment process options, ISV and ISG, have been extensively researched for application at the SDA and have been retained as representative technologies for treating waste in the SDA. Two supporting reports present detailed descriptions of ISV and ISG technology (Thomas and Treat 2002; Armstrong, Arrenholz, and Weidner 2002) and provide case studies that detail implementations of the technologies, including results of previous INEEL studies directed at developing site-specific design criteria. The remaining two process options, soil vapor extraction and thermal desorption, also have been retained to specifically address areas within the SDA containing high concentrations of VOCs. A discussion of each retained process option is provided in following subsections.

2.5.4.1 High-Pressure Jet Grouting. High-pressure grouting, commonly referred to as jet grouting or in situ grouting (ISG), is a process that entails injecting a slurry-like mixture of cements, chemical polymers, or petroleum-based waxes into contaminated media. Grouts are specially formulated to encapsulate contaminants, isolating them from the surrounding environment. Grouting is accomplished without displacing contaminants or debris or causing the ground to heave. Overall volume of the waste site remains constant, but density of the site is substantially increased as grout fills void spaces between discreet waste components.

As summarized by Armstrong, Arrenholz, and Weidner (2002), ISG has been approved by regulating agencies and implemented at several small-scale sites across the DOE complex, including successful deployment at the SDA Acid Pit (Loomis et al. 1998). Though ISG has not been applied to sites as large and with as many radiological and chemical hazards as the SDA, research has been conducted at the INEEL using simulated buried waste pits in an effort to evaluate efficacy of ISG. Results of past applications at other sites and the INEEL research are promising.

As a result of evaluating grouting process options, high-pressure grouting was identified as a representative process option. Low-pressure or permeation grouting is typically applied in areas with high soil permeability and is, therefore, not widely applicable at the SDA. Though some areas may exist in the SDA with large void space and may technically be groutable by low pressures, the persistence of fine-grained soil and clay mixed with the waste would preclude permeation grouting. Therefore, jet grouting was evaluated as a universally applicable process option.

2.5.4.2 In Situ Vitrification. In situ vitrification is a process wherein electrodes are inserted into the ground to generate very high temperatures that convert buried waste and contaminated soil into a glass-like substance. Off-gases from the process are drawn into a large hood and treated before the cleaned gas is discharged to the atmosphere. Most nonmetallic, inorganic materials, such as soil and sludge, would melt and subsequently solidify into a hard, dense material resembling obsidian. Metallic materials would melt and settle to the bottom of the zone. The process destroys organic contaminants and immobilizes inorganic contaminants in a very durable and leach-resistant form. Though still an innovative technology, ISV has been implemented at a number of contaminated soil and waste sites worldwide. Full-scale melts ranging from 200 tons to 1,400 tons, with depths exceeding 6 m (20 ft), have been completed. An evaluation of ISV applicability to the SDA, including a summary of four recent deployments, is provided in the comprehensive report developed for this PERA (Thomas and Treat 2002).

Numerous investigations have been conducted to evaluate ISV applicability to the SDA. Because it can be applied to a wide variety of waste streams and is compatible with the type of interstitial soil found at the SDA, ISV was retained as a representative process option. Some problems have been encountered with the technology, primarily safety concerns controlling the molten material and associated off gases, but recent advances have improved it. The modified approach, referred to as subsurface planar ISV, has potential application at the SDA, by allowing melting to be conducted entirely belowground, under a layer of unmelted soil. This would mitigate many of the hazards associated with traditional ISV.

The ISV technology has been shown to be effective on various waste types and is potentially applicable at most areas within the SDA; however, site-specific treatability tests would be required to verify specific design and implementation requirements. Further, because highly metallic waste streams remain separated, even after melting, ISV would not be applied to high steel content waste streams in certain SVRs, trenches, and pits.

2.5.4.3 Soil Vapor Extraction. For soil vapor extraction (SVE), also known as soil venting or vacuum extraction, a vacuum is applied through wells near or within the contamination source. Volatile constituents of contaminant mass evaporate, and vapors are drawn toward extraction wells. Extracted vapor is then treated, commonly with carbon adsorption, then released to the atmosphere. Alternatively, treated vapor can be injected to the subsurface if permitted by applicable state laws. Increased airflow through the subsurface also can stimulate biodegradation of some contaminants, especially those that are less volatile. Extraction and injection wells may be installed either vertically or horizontally.

Permeability of soil or waste media affects rates of air and vapor movement—the higher the permeability, the faster the movement and (ideally) the greater the amount of vapors that can be extracted. The structure and stratification of soil or waste media are important to SVE effectiveness because they can affect how and where soil vapors will flow under extraction conditions. Structural characteristics (e.g., layering and fractures) can result in preferential flow behavior that can lead to ineffective or significantly extended remedial times, if preferential flows are positioned so that induced airflow occurs outside the area of contamination. Other factors, such as the moisture content and organic content, will also affect effectiveness of extraction. Reductions in VOC concentrations in excess of 90% are difficult to achieve using SVE.

The technology is typically applicable only to volatile compounds with a Henry's law constant greater than 0.01 or a vapor pressure greater than 0.5 mm (0.02 in) Hg. In situ SVE will not remove heavy oils, metals, polychlorinated biphenyls (PCBs), or dioxins. Given available historical records and soil gas surveys, SVE would be effective for the majority of the VOCs (CCl_4, tetrachloroethylene (PCE), and methylene chloride) in the SDA. Advantages of the SVE technology include easy installation, minimal disturbance to site operations, short treatment times (usually 6 months to 2 years under optimal conditions), and relatively low capital and maintenance costs.

Soil vapor extraction has proven effective in reducing concentrations of VOCs and certain semivolatile organic compounds (SVOCs) and petroleum-based contaminants at numerous hazardous waste sites in the United States, including the SDA. The existing Organic Contamination in the Vadose Zone (OCVZ) treatment system at the SDA employs the SVE technology and has been successful in removing dispersed VOC contamination. The OCVZ system consists of five vapor extraction wells, an off-gas treatment system to destroy organic contaminants present in the vapor removed from the extraction wells, and soil vapor monitoring wells to monitor performance of extraction wells and verify attainment of the RAOs for OU7-08. The OCVZ project is limited to remediating the vadose zone and does not directly address either buried waste or groundwater.

Vapor extraction without thermal enhancements has been retained for developing remedial action alternatives requiring pretreatment to reduce VOC concentrations. Thermal enhancements for SVE, as discussed in the following subsection, were retained for consideration in waste areas where additional or accelerated removal of VOCs may be warranted.

2.5.4.4 In Situ Thermal Desorption. In situ thermal desorption is a developed technology that uses various sources of electrical heat or injection of hot air or steam to increase volatilization of VOCs and SVOCs and thereby facilitate extraction by conventional SVE systems. The process requires heat-resistant extraction wells to withstand the higher operating temperatures. Thermal desorption is normally a short- to medium-term technology that includes various suboptions:

- Thermal conduction—Thermal conduction uses electrical resistance heating elements installed in waste in a thermal-well array. Waste and contaminated soil are heated to temperatures between 600 and 1,000°F to vaporize and destroy most organic materials. Achieving temperatures up to 800°F may take three months or longer.

- Electrical resistance heating—Electrical resistance heating uses electrical current to heat less permeable but relatively electrically conductive media such as clay and fine-grained materials. Electrodes are placed directly into the affected media and activated, creating an electrical current that passes through the media to generate heat. The heat dries out the media, resulting in fracturing, which makes the media more permeable and allows SVE to more readily remove contaminants.

- Radio frequency and electromagnetic heating—Radio frequency heating uses electromagnetic energy to heat soil and waste to enhance SVE. The technique entails heating soil or waste using rows of vertically embedded electrodes. Heated soil or waste volumes are bounded by two rows of ground electrodes with energy applied to a third row midway between the ground rows. The three rows act as a buried triplate capacitor. When energy is applied to the electrode array, heating begins at the top center and proceeds vertically downward and laterally outward through the media between the ground electrodes. The technique can heat soil to approximately 600°F.

- Hot air or steam injection—The hot air or steam injection process employs hot air or steam injected below the contaminated zone. Some VOCs and SVOCs are stripped from the contaminated zone and removed using SVE. Achieving temperatures up to 800°F may take three months or longer. Forced injection of hot air or steam could mobilize contaminants either to the underlying vadose zone or in contaminated gases to the environment if the gas-capture zone of the SVE system is not sufficient.

Using in situ thermal desorbtion (ISTD) would increase the rate and degree of extraction of VOCs and SVOCs over that achievable by conventional SVE and potentially destroy other hazardous organic materials by oxidation or pyrolysis. The results of the screening identified thermal conductance as the representative technology for ISTD. ISTD is potentially implementable at the SDA, however, treatability tests would be necessary to confirm that the technology could achieve required performance objectives at the SDA. The likelihood of an underground fire in dried waste consisting of combustible materials is increased for all options, especially in areas that contain significant amounts of combustibles and sodium nitrate, an oxidizing salt. Additional safety analyses and testing may be required during the design phase.

2.5.5 Retrieval

The retrieval GRA consists of excavating and removing pits and trenches containing the Rocky Flats Plant TRU waste within the SDA. Overburden soil, interstitial soil, and possibly impacted underlying soil over the waste would be removed as well. TRU pits (Pits 1 through 6 and 9 through 12) and trenches (Trenches 1 through 10) contain TRU, LLW, and mixed waste. Retrieving low-level radioactive and hazardous soil and buried waste from a site is a proven and reliable approach that offers many potential benefits. A summary of historic retrieval actions conducted at DOE facilities, including Hanford, Rocky Flats, Los Alamos, Fernald, and the INEEL, is provided in the supporting report (Sykes 2002). The report additionally offers a summary of special excavators used at different facilities.

However, retrieval techniques for TRU waste have not been proven to the same extent and will require site-specific and innovative design elements to ensure protection of human health and the environment.

Either completely or partially removing waste from a site allows it to be treated to reduce toxicity and mobility of many chemicals. Removed and treated material can then be disposed of in an approved engineered facility. Retrieval removes or greatly reduces risk associated with the site if the retrieved waste is disposed of off-Site or isolated from the environment. Typically, by removing waste and reducing the contaminant source, long-term site monitoring and maintenance requirements can be reduced. Further, with complete removal of waste, the site could be released for unrestricted access following the CERCLA 5-year review.

However, retrieving and disposing of waste materials, such as those buried in the SDA, are time-consuming and expensive. One of the greatest concerns in retrieving buried radioactive waste and soil is increased potential for worker exposure, contamination spread, and off-Site release. Waste poses a significant risk of inhalation; to accidentally inhale even minute quantities of TRU materials such as those present at the SDA would be dangerous. Technologies such as supplied air excavators, foggers, and ventilation systems are available and have been demonstrated to reduce worker risk.

The retrieval GRA has been divided into two technology types—contamination control and excavation. Descriptions of individual process options and results of the screening evaluation are provided in Appendix B. A summary of results of e screening is provided in Figure 2-11 and the following subsections.

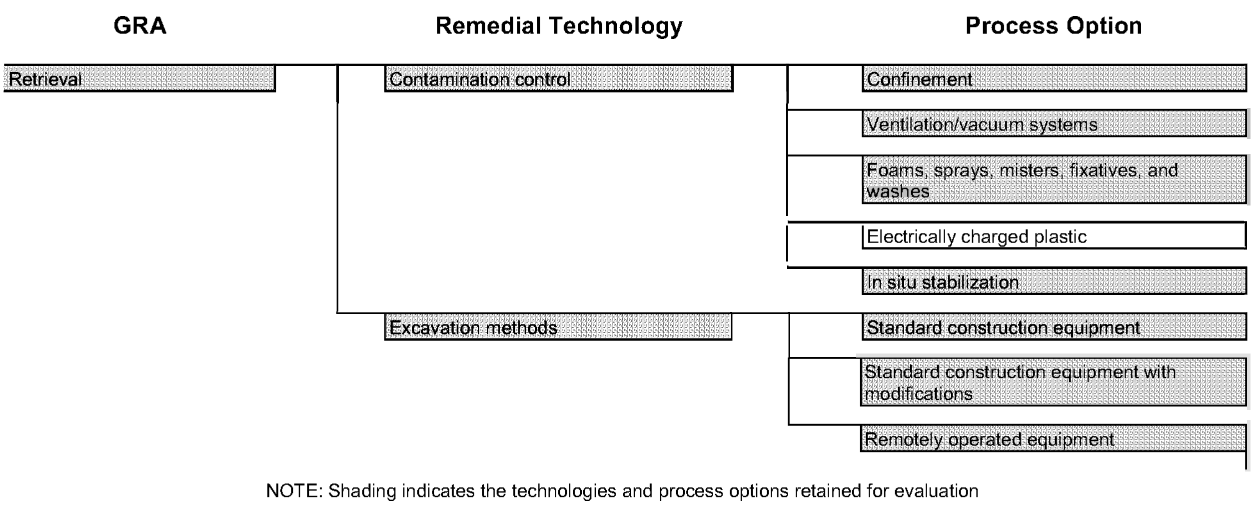


Figure 2-11. Retrieval screening summary.

2.5.5.1 Contamination Control. Controls during waste retrieval are needed to minimize the spread of contamination and control the source. Depending on site-specific conditions and materials present (e.g., boxes, tanks, and plastic debris), various different controls may be used. In general, controls are grouped into two categories—those used before retrieval and those used during retrieval. Both types can be effective at controlling contamination, thus decreasing the potential for exposure, the costs of operation and maintenance of equipment, and the cost for decontamination. Process options for contamination control include the following:

- Confinement—Confinement enclosures constructed from plastic, metal, fiberglass or other materials are used to prevent spreading airborne contaminants by enclosing a piece of equipment, work area, or an entire site. Enclosures may be relatively lightweight and portable (e.g., Moducon) or may be substantially sturdier and less portable (e.g., Butler Building). Enclosures are typically double-walled to minimize potential for contaminant releases.

- Ventilation and vacuum systems—Ventilation systems use laminar airflow at the dig-face of an excavation and within enclosures to direct dust to high-efficiency particulate air (HEPA) filter units. Vacuum systems are used to remove loose particles from equipment and structures and draw in dust and debris generated during excavation activities.

- Foams, sprays, misters, fixatives, and washes—Identified process options can be applied to perform various functions including controlling odors, VOCs, dust, and other emissions; creating a barrier between work surface and the atmosphere; settling loose airborne contamination; and decontaminating personnel and equipment. Processes are readily available in nontoxic, nonhazardous, nonflammable, and biodegradable forms consisting of water and polymer mixtures.

- Electrostatics—Electrically charged plastic and electrostatic curtains can be used as barrier walls to minimize spread of contamination from enclosed areas. Curtains can be used upstream of emission filtering systems to neutralize charged dust particles.

- In situ stabilization —In situ stabilization can be performed before initiating excavation operations to control contamination in the soil and waste matrix. Grout, resin or polymer (e.g., EKOR) may be injected into waste or soil to solidify material and minimize contaminant releases during retrieval. Stabilization also could be performed using ISV and ground-freezing technologies.

With one exception, all process options identified have been retained for consideration in developing remedial action alternatives. Electrically charged plastic is not applicable in the large open excavation area required for retrieving the SDA waste and therefore was not retained. Appendix B contains details about all process options.

2.5.5.2 Excavation. Retrieving soil and buried waste can be achieved with a number of different technologies, including conventional heavy equipment, standard construction equipment with modifications (e.g., sealed and pressurized cabins with filtered intakes and extracts or supplied air), and remotely operated equipment and controls. Most equipment used for excavation of soil and buried waste is standard heavy construction equipment proven for use at hazardous waste sites across the nation. Given the nature of material and chemicals present at the SDA, technologies such as remotely operated equipment and hermetically (airtight) sealed equipment with filtered or supplied air also apply. Radioactive material present in the SDA is a significant external exposure concern for remediation workers, has potential for airborne release and internal exposures (e.g., inhalation and ingestion), and may be difficult to control during retrieval actions, as demonstrated by past retrieval efforts. However, technologies are available to address these issues and protect workers and the environment. A summary of potentially available remote excavators and modified standard equipment is presented in Table 2-1.

A number of end effectors with specialized designs have been developed to facilitate retrieving various waste forms. Designs include grappling devices for waste containers and debris, water jets, magnets, and vacuum systems. A summary of potentially available end-effectors is presented in Table 2-2.

Table 2-1. Description of retrieval equipment.

Technology	Description
Remote Excavators	
Brokk	Remote-controlled excavator with telescoping arm capable of full articulation. Available with several different end-effectors that could be used for hammering, cutting, and scooping waste. The largest Brokk can reach approximately 4 m (13 ft) belowground surface (bgs).
Keibler Thompson	Remote-controlled excavator with telescopic boom capable of moving in three dimensions. Available with several end-effectors. The largest Keibler Thompson machine can reach approximately 4.9 (16 ft) bgs.
Remote-operated excavator	Excavator mounted on a wheeled undercarriage that was developed to retrieve unexploded ordnance. A television provides images for remote excavation. The only such excavator in existence is currently used at an air force base.
T-Rex, front shovel excavator that requires modification for use	A teleoperated, heavy-lift, long-reach excavator designed to retrieve boxes, drums, and containers with a front shovel excavator. Controls can be operated up to 381 m (1,250 ft) from the excavator.
Front-end loader with a 2.1 m^3 (2.75 yd^3) bucket	Remote control developed for use on front-end loader. Provides 3-D color video/audio feedback and can be controlled from 457 (1,500 ft) away. System could be modified for use on excavators.
Teleoperated excavator using T-Rex remote control kit	Remote-controlled excavator (bucket and thumb) adapted for hazardous environments, such as UXO, through sensors, controllers, and hydraulic components.
Remote excavator vehicle system experimental platform based on an excavator	Remote-controlled, tethered platform for excavator. Attachments can grasp objects, sift soil, and make excavator act as a bulldozer. A clamshell and air-jet vacuum system can also be attached.
Automated ordnance excavator	Remote-controlled excavator with extended reach capability, developed for UXO removal. Can grasp objects such as drums and boxes.
Small emplacement excavator	Military tractor with front-end loader and backhoe remote operation for retrieving buried waste and soil. System can be controlled from 0.8 km (.5 mi) away.
Remote excavator, Hitachi excavator, innovative end-effector, and self-guided transport vehicle	Standard excavator with end-effectors (such as buckets, rippers, and breakers) used for buried waste retrieval. System can be controlled inside cab, via a remote tether, or from 762 m (2,500 ft) away.
Modified bobcat	Remote-controlled skid steer loader with a Bobcat vehicle base with barrel grapple, sweeper and bucket attachments. Modified for hazardous environments, remote kit for other excavators.
Standard Construction Equipment With Modifications	
Sealed and pressurized cabin, with filtered air intakes and extracts	Standard construction equipment with modifications made to the cabins. The sealed and pressurized cabin uses filtered air (through HEPA filtration).
Sealed and pressurized cabin, with supplied air	Standard construction equipment with modifications made to the cabins. The sealed and pressurized cabin uses supplied air.

UXO=unexploded ordinance; HEPA=high efficiency particulate air

Table 2-2. Remote end-effectors.

Technology	Description
Safe excavation	High-pressure probe dislodges compacted soil, other hardened materials using an air-jet/vacuum end-effector system. Vacuums up soil.
2-armed, tethered hydraulically powered interstitial conveyance system	Crane-deployed with two excavators and vacuums designed for low-level radiation fields. Maximum pickup load of 700 lb.
Tentacle, highly manipulative	Teleoperated manipulator and bellows actuator.
Hydraulic impact end-effector	Water cannon for tank applications, which is attached to a robotic manipulator arm and used to break up monolithic hard cake forming around risers in tanks.
Schilling Tital II	Manipulators deployed by crane for selective retrieval. Basic components include hydraulic system, positioning system, electronics module, and mechanical interface.
Mineclaw	Manipulator with strong electro-magnet to pick up barrels. Custom grapple with a several hundred pound payload and an electro-magnet to retrieve metals.
Confined sluicing end-effector	Water-jet designed for waste tank clean-out. Uses high-pressure water-jets to cut material into small pieces and evacuate with a vacuum jet pump. Captures slurry water.
Soil skimmer	Skimmer removes soil overburden in 8-, 10-, 15-cm (3-, 4-, and 6-in.) increments. Adjustable depth controls the depth of cut without disturbing soil underneath.
Innovative end-effector	Consists of three assemblies: a thumb, an attachable/detachable integrated transfer module, and a shovel assembly capable of soil retrieval and dust-free waste dumping.
Couplers, quick-change	Available in manual and hydraulic versions. Used on various buckets, rakes, clamps, rippers, and other end-effectors.
Vacuum systems	Nuclear-grade vacuum systems for contamination control and retrieval of soil with HEPA filtration and critically safe waste containers.

HEPA=high efficiency particulate air

Most of the required equipment and technologies for excavation or retrieval have been proven in highly contaminated environments. For example, remote excavators have been proven successful in waste retrieval simulations and have been used throughout DOE facilities for D&D&D. In addition, shielded excavators have also been used successfully (e.g., Hanford), and hermetically sealed vehicles have been used successfully (e.g., Maralinga). Generally, hermetically sealed retrieval equipment is less expensive, needs less maintenance, is capable of more precise digging, and can be operated faster than remote equipment. In some environments, shielding (e.g., Lexan windows) is required on equipment to protect workers from potential explosions and radiation. Shielded excavators have been proven at Hanford in the 100 N-Reactor Area. Filtered or supplied air can be added to equipment to protect operators, as has been proven at many sites, including Maralinga and Calvert City. A more detailed discussion of conventional heavy equipment, hermetically sealed equipment, and remote technologies and their potential applicability to the SDA is presented in a supporting report (Sykes 2002). Additional information can be found in *Survey of Materials-Handling Technologies Used at Hazardous Waste Site* (EPA 1991), *Hot Spot Removal System: System Description* (INEEL 1997), and *Technical Alternatives Baseline Report* (BHI 2000).

All excavation process options have been retained to offer the flexibility to address potentially diverse SDA waste.

2.5.6 Ex Situ Treatment

Ex situ treatment technologies are included in developing remedial alternatives for their ability to reduce toxicity, mobility, or volume of contaminants, as required to meet specific disposal and transportation requirements. Regulatory requirements for TRU disposal and transportation are different than for non-TRU waste. Therefore, treatment requirements are correspondingly different. All retrieved waste would be transported to a new waste processing facility to be constructed on or adjacent to the SDA, where any required ex situ treatment would take place. Transuranic waste would undergo packaging and characterization necessary to satisfy the waste acceptance criteria (WAC) of the Waste Isolation Pilot Plant (WIPP). Treatment requirements include solidifying liquids, removing prohibited items, and eliminating any ignitability, corrosive, or reactive characteristics. Because WIPP is exempt from Resource Conservation and Recovery Act (RCRA) LDRs, specific ex situ treatment of mixed TRU waste for organic and inorganic contaminants will not be necessary. Conversely, non-TRU waste separated from the TRU waste would undergo various types of physical, chemical, and thermal treatments to remove hazardous organics, to fixate regulated metals and radionuclides, and to prepare waste for onsite disposal. The WAC for an onsite landfill would be based on regulatory requirements (i.e., RCRA LDRs) and risk-based considerations for long-term protection of human health and the environment.

The Advanced Mixed Waste Treatment Facility (AMWTF), recently constructed within the TSA, will primarily treat TRU waste, alpha-contaminated LLW, contact-handled mixed waste, and other selected waste stored at the TSA. The AMWTF is scheduled to start shipping waste to the WIPP in 2003, in accordance with the September 1995 INEEL Settlement Agreement. Though the AMWTF has some similar capabilities to those required for ex situ treatment of the SDA waste, the facility does not have aggressive treatments for hazardous waste necessary to satisfy RCRA LDRs for disposal of mixed, low-level, RCRA-regulated waste. As such, the facility will not be suitable for treating MLLW retrieved from the SDA. Furthermore, it is assumed that facilities within the AMWTF are fully dedicated to treating TSA waste and that additional capacity is unavailable for treating any TRU waste retrieved from the SDA.

Potential process options for onsite ex situ treatment are grouped under five general technology types: (1) physical, (2) chemical, (3), thermal, (4) electrokinetic, and (5) biological. A list of ex situ treatment process options associated with each technology, along with specific screening comments related to effectiveness, implementability, and cost, is presented in Appendix B. Screening was based on each technology's applicability to the waste to be processed, degree of proven technical development, safety, capital and operating costs, complexity, reliability, perceived public acceptance, and ability to handle the expected volume of waste. Figure 2-12 summarizes the screening.

Screening eliminated two of five remedial technologies identified. Biological treatment was not retained for consideration in developing remedial alternatives. Though it is potentially effective for VOC COCs (CCl_4, PCE, and methylene chloride), biological treatment is more suitable for semivolatile organic contaminants. Biological treatment generally requires extensive pretreatment of contaminated media and is frequently a time-consuming process requiring large areas to facilitate treatment. Electrokinetic treatment was eliminated based on complexity, the need for two secondary recovery systems, significant waste pretreatment requirements, and an unproven record for the type of waste to be processed.

Of the three remaining remedial technologies, physical, chemical, and thermal treatment, 16 process options were retained for potential assembly into remedial alternatives.

GRA	Remedial Technology	Process Option
Ex situ treatment	Physical treatment	Screening and classification
		Sizing
		Compaction
		Gravity separation
		Magnetic separation
		Electrostatic separation
		Gamma monitor, conveyor, gate system
		Flotation
	Chemical treatment	Fixation and stabilization
		Soil washing
		Acid extraction
		Solvent extraction
		Dehalogenation
		Hydrolysis
		Redox manipulation
		Neutralization
	Thermal treatment	Incineration
		Catalytic oxidation (off-gas treatment)
		Pyrolysis
		Steam reforming
		Supercritical water oxidation
		Thermal desorption
		Vitrification (plasma torch and direct current arc melter)
		Molten metal system
		Molten salt system
	Electrokinetic treatment	Mediated electrochemical oxidation
	Biological treatment	Aerobic degradation

NOTE: Shading indicates technologies and process options retained for evaluation.

Figure 2-12. Ex situ treatment screening summary.

2.5.6.1 *Physical Treatment.* Physical treatment involves separating and sorting waste stream material according to physical and radiological characteristics. Physical treatment process options also include waste compaction for volume reduction. Of the identified physical treatment process options, only magnetic separation was screened out because of its developmental status and its poor suitability for SDA waste characteristics. Remaining process options were all retained for potential incorporation into retrieval alternatives.

2.5.6.2 *Chemical Treatment.* Chemical treatment entails separating and extracting organic and radioactive constituents from waste, neutralizing acid and caustic substances, and stabilizing treated waste. Four of eight process options for chemical treatment passed the screening. Soil washing, dehalogenation, hydrolysis, and redox manipulation were eliminated for reasons of limited applicability to the SDA waste, state of technical development, and cost-effectiveness.

Stabilization has been identified as the representative technology to treat MLLW streams, which contain a number of RCRA metals including mercury and lead. The RCRA LDRs are assumed to apply to the MLLW that will be disposed of in an on-Site or off-Site disposal facility. This process option effectively immobilizes radioactive and hazardous constituents in waste by mixing additives that bind waste into a stable waste form. Stabilization has been researched at INEEL in site-specific applications, but additional remedial design studies would be needed to define process variables, such as type of additives, concentrations, and mixing times (Armstrong, Arrenholz, and Weidner 2002).

2.5.6.3 *Thermal Treatment.* Thermal treatment removes and destroys hazardous chemical constituents of waste and enables volume reduction. The evaluation presented herein assumes ex situ thermal treatment of the waste will be necessary only for the non-TRU fraction of the waste, because thermal treatment is not required for TRU waste. It is also assumed that WIPP will be granted approval to receive nonliquid PCB-contaminated waste before operating the treatment facility.

Five of nine process options for thermal treatment passed the screening. Retained technologies include incineration, steam reforming, thermal desorption, vitrification, and chemical oxidation, which was retained as an off-gas treatment. Pyrolysis, supercritical water oxidation, molten metal system, and molten salt system were eliminated for reasons including state of technical development, volume of secondary waste generation, safety and reliability, and lack of applicability to the SDA waste.

Incineration has been widely used as an effective process option to treat potentially variable waste streams such as those in the SDA. This process option, however, is generally considered nonimplementable at the INEEL because of concerns expressed by the agencies and major stakeholders, including neighboring communities, over the incinerator proposed as part of the AMWTF. As a result, the DOE continues to extensively research existing and emerging process options to identify potential alternatives to incineration. In a study conducted by the Secretary of Energy Advisory Board (DOE 2000), a number of potential process options were identified as promising, including thermal desorption, plasma torch, direct current arc melter, and steam reforming. Additional testing of specific technologies as planned in the April 2001 Action Plan (DOE 2001) will further refine the list. However, because results of this continuing research are currently unavailable, all process options have been retained for consideration in the final alternative design. Incineration—based solely on technical and economic reasons—passed the screening; therefore, it has been retained for consideration but was not selected as the representative technology.

Steam reforming has been identified as the representative technology and with its associated off-gas treatment system, the technology has the ability to treat the waste and destroy the VOCs and SVOCs. Peak temperature of waste is significantly lower than for incineration, which would allow plutonium and most other radionuclides and heavy metals to be retained with the solids and ash. The option also involves lower off-gas volumes than incineration, which minimizes potential for particulate transport to the off-gas system. High-temperature steam reforming of volatile gases, generated from the waste in a separate chamber, completes destruction of the organics. Resulting gases are H_2, CO, H_2O, and CO_2, and these can be directly discharged to the atmosphere after off-gas cleanup. Because a thermal oxidizer is not used, steam reforming is not incineration.

2.5.7 Disposal

The Disposal GRA has been divided into two primary technologies—onsite storage or disposal, and off-Site disposal. A discussion of process options, along with specific screening comments related to effectiveness, implementability, and cost, is provided in Appendix B. A listing of the process options summarizing results of the screening process is presented in Figure 2-13.

Capabilities of identified on-Site and off-Site disposal facilities in terms of their acceptance of LLW, MLLW, high-level mixed waste (HLMW), and high-level waste (HLW) are summarized on Figure 2-14. As shown, a number of on-Site and off-Site facilities are potentially capable of disposing of retrieved waste from the SDA. However, the only location currently permitted to receive TRU waste is the WIPP facility located near Carlsbad, New Mexico. For HLW and HLMW, the only potential disposal site is the Yucca Mountain facility located in Nye, Nevada. Currently, however, this facility is being further evaluated and is unavailable for waste disposal.

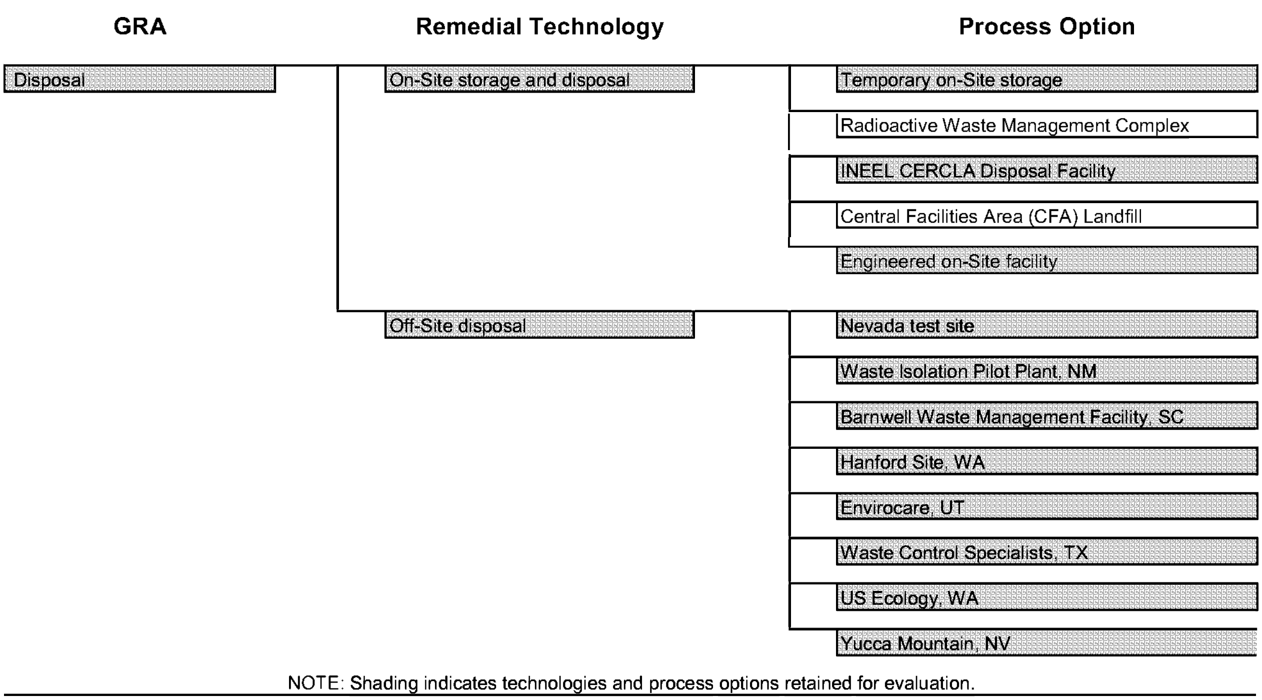


Figure 2-13. Disposal screening summary.

Disposal Site	Waste Type						
	Debris		Soil			LLW	HLW
	TRU	MLLW	TRU	MLLW	HLMW		
On-Site Disposal							
SDA[a, b]				X[c]		X	
CFA							
ICDF		X		X		X	
Off-Site Disposal							
Waste Isolation Pilot Plant[d]	X		X				
Barnwell Waste Management Facility						X	
US Ecology, Inc.						X	
Envirocare of Utah		X		X		X	
Hanford Site		X		X		X	
Nevada Test Site		X		X		X	
Yucca Mountain					X		X
Waste Control Specialists[e]							

a. Storage for TRU available at the TSA in the RWMC.

b. Advanced Mixed Waste Treatment Facility (AMWTF) available in 2003 at the RWMC for treatment of TRU waste.

c. After treatment for mixed waste characteristics to meet LDRs.

d. Staging, Storage, Sizing and Treatment Facility (SSSTF) available for on-Site treatment.

e. TRU storage available on-Site. LLW and MLLW disposal permits are pending. Currently, only available for disposal of exempt level of radioactive material.

Figure 2-14. Disposal site options.

2.5.7.1 On-Site Disposal Options. On-Site disposal options potentially include temporary storage, construction of engineered disposal facility within the RWMC, and the following three active or proposed landfill operations:

- Radioactive Waste Management Complex—Active cells in the SDA make up a shallow landfill, which currently accepts LLW for disposal. The SDA can receive waste that began as RCRA-characteristic waste, has been subsequently treated to remove the characteristic, and now meets LDRs. The SDA is not permitted for RCRA-listed mixed waste. Upon arrival, waste is examined, and radiological surveys are performed to ensure that radiation and contamination meet requirements. The TSA, also located in WAG 7, accepts TRU waste for storage. Current operations at the TSA include examination, segregation, certification, and interim storage of solid contact-handled and remote-handled TRU waste.

- Central Facilities Area landfill—This unlined landfill accepts nonhazardous industrial waste generated at the INEEL site.

- INEEL CERCLA Disposal Facility landfill—Located at the Idaho Nuclear Technology and Engineering Center for WAG 3, the ICDF landfill is currently under design and is scheduled to accept LLW beginning in 2003. The facility is intended for the disposal of contaminated soil and debris resulting from waste generated within the INEEL during CERCLA cleanup actions. The ICDF facility will include a landfill, an evaporation pond, a treatment facility, and an associated staging and storage annex. The facility will accept RCRA-characteristic and listed waste in accordance with its specified WAC. If waste is not from WAG 3, then the characteristic that made the waste hazardous must generally be removed as specified by the WAC.

The ICDF landfill has been retained as a potentially viable option for the disposal of retrieved LLW waste and soil. However, available capacity within the landfill to accommodate waste and soil from WAG 7 is uncertain. Based upon current information, active storage facilities within the SDA and TSA will be unavailable for consideration when developing alternatives because of capacity and operational constraints. Because the Central Facilities Area landfill facility can accept only nonhazardous waste, it also is eliminated from further consideration.

Temporary onsite storage for TRU and non-TRU waste streams within the RWMC was retained as a process option to provide staging and accommodate material handling requirements during retrieval, treatment, and permanent disposal activities. Temporary storage facilities would be designed in accordance with regulatory standards to protect workers and the environment.

An engineered on-Site disposal facility at the RWMC was retained for developing remedial alternatives. The facility would be designed for permanent storage of LLW and MLLW and soil retrieved from the SDA. Because of regulatory constraints and potential design requirements, constructing a permanent onsite storage facility for retrieved TRU waste was not considered in this PERA. A number of potential design options are available for constructing a permanent onsite LLW disposal facility having concrete vaults and engineered disposal cells. The design recently established for the ICDF landfill was identified as the representative technology retained for developing an onsite disposal alternative. The facility would be constructed within limits of the SDA and sized to accommodate projected volume of retrieved LLW and treated MLLW and contaminated soil. A cross section showing specific design elements is provided in Figure 2-15.

2.5.7.2 Off-Site Disposal Options. Off-Site disposal involves shipping waste to an approved facility outside the INEEL. Several off-Site disposal options are available. A list of the facilities, along with their waste acceptance considerations, is presented in Figure 2-14. The general location of each facility is shown on Figure 2-16. Each facility is described briefly below.

- Waste Isolation Pilot Plant—Located in Carlsbad, New Mexico, WIPP is an underground repository that accepts defense-generated, contact-handled TRU waste for disposal. Remote-handled TRU waste is expected to be accepted in the near future, following approval of a proposed RCRA permit modification. Mixed TRU waste is acceptable under specified waste codes. Waste that exhibits RCRA characteristics of ignitability, corrosivity, or reactivity is unacceptable. Total capacity of the facility, as currently designed, is estimated at 175,600 m^3 (229,676 yd^3), which is expected to be filled to capacity by 2034. Transportation to the WIPP from the SDA will be by truck.

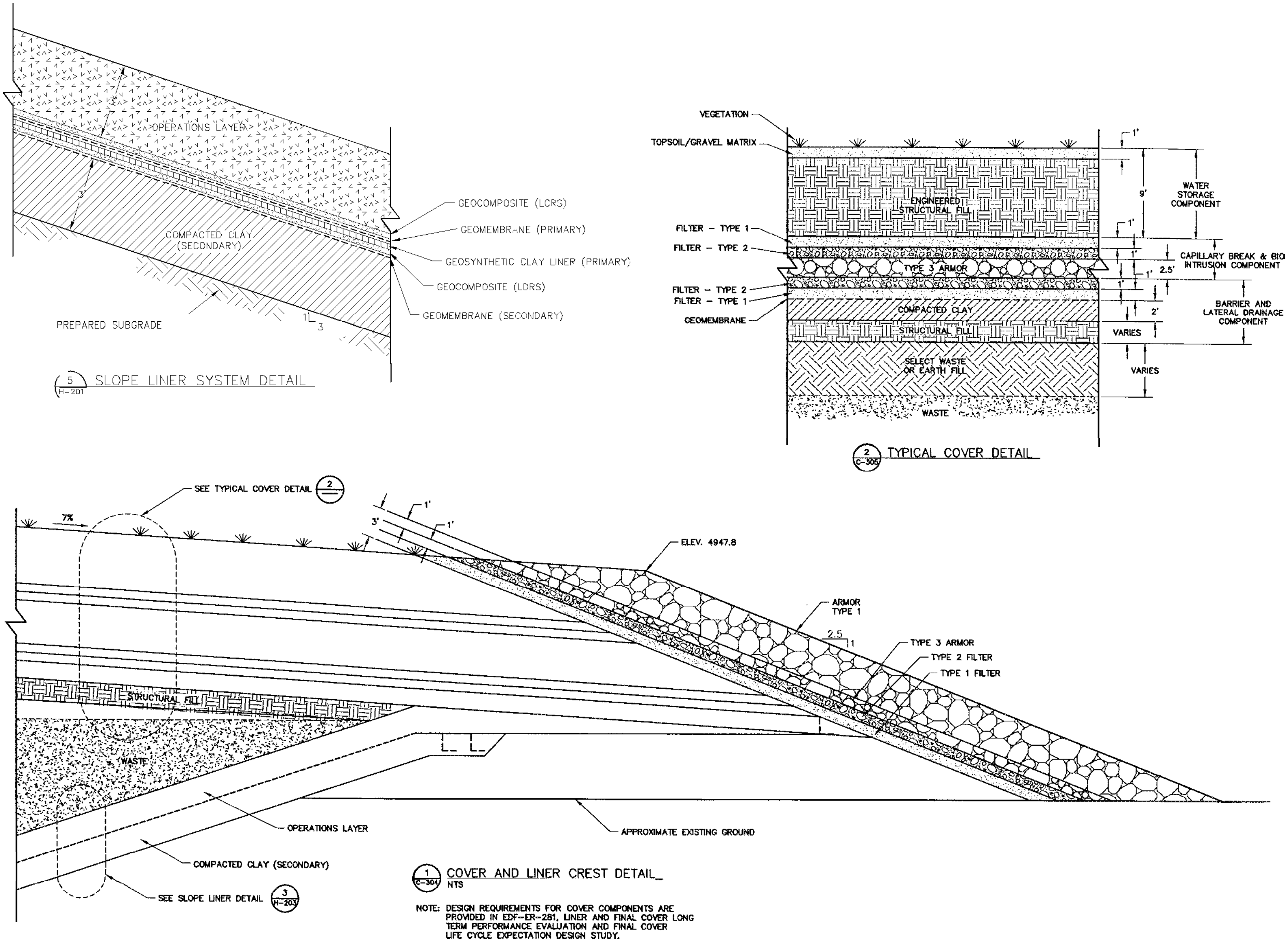


Figure 2-15. INEEL CERCLA Disposal Facility landfill design elements.

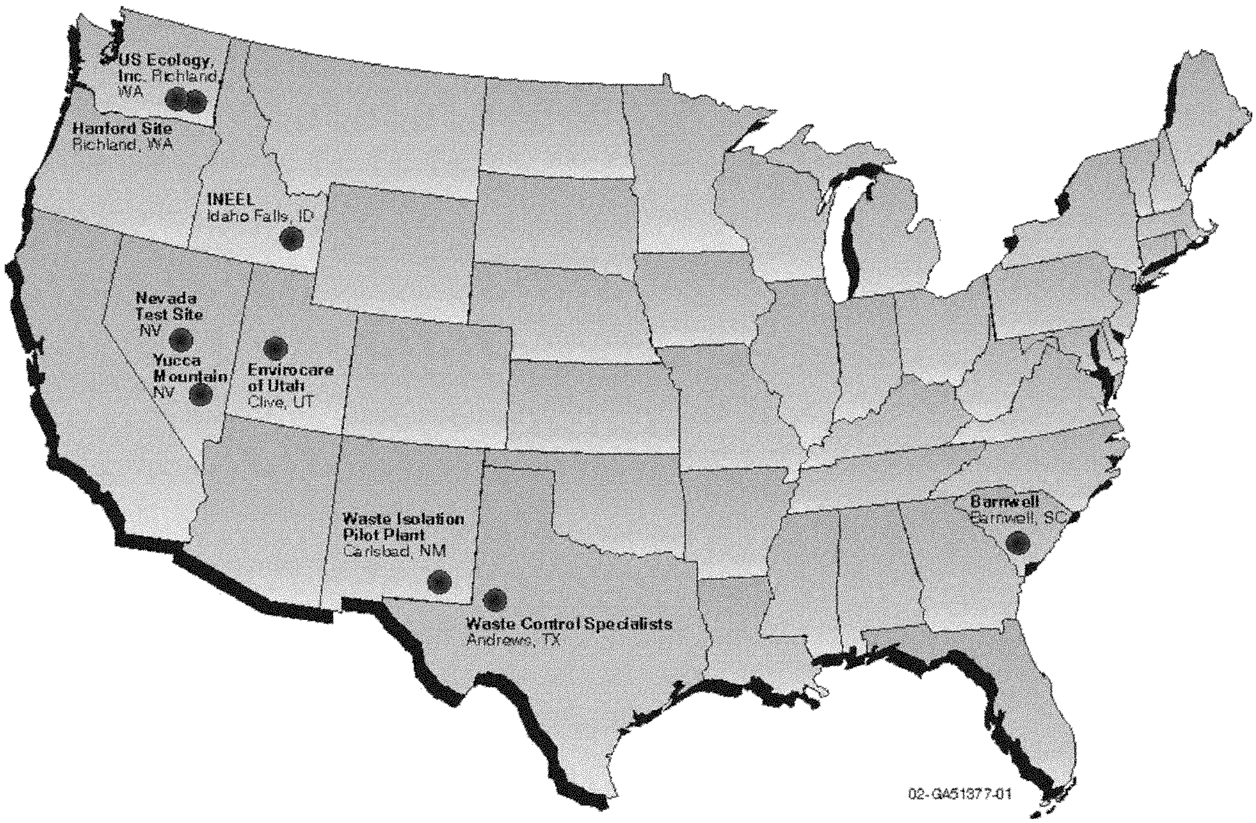


Figure 2-16. Disposal site locations.

- Barnwell—Located in Barnwell, South Carolina, this facility is a 235-acre commercial operation that accepts LLW. Waste shipments are accepted by public highway only. Site disposal consists of shallow land burial in concrete vaults located in engineered earthen trenches. No MLLW is accepted. Waste containing TRU radionuclides is acceptable in accordance with facility WAC. Stabilization is required for waste containing isotopes with greater than 5-year half-lives having a total specific gravity greater than 1 µ/cc. Treatment is unavailable at Barnwell. In 2000, South Carolina passed a law limiting annual volume of waste accepted at Barnwell from any generator through June 30, 2008. Limits are based on a declining annual volume of 2,265 m^3 (2,963 yd^3) in 2002 to 991 m^3 (1,296 yd^3) in 2008. After June 30, 2008, only waste generated by the Atlantic Compact Region will be accepted for disposal at Barnwell.

- US Ecology, Inc.—Located in Richland, Washington, US Ecology is a 100-acre commercial facility that accepts LLW for disposal in shallow trenches. Since 1993, the site has been the regional commercial LLW disposal site for 11 western states (Northwest and Rocky Mountain Compact States). Mixed low-level waste is not accepted and treatment is unavailable at the facility. Radioactive waste containing radium or TRU radionuclides is acceptable in accordance with the facility WAC. The site, which is scheduled for closure in 2056, has a remaining capacity of approximately 1,245,942 m^3 (1,629,630 yd^3). Currently, a 2,832 m^3 (3,704 yd^3) annual limit applies to the site. The site is accessible only by truck.

- Envirocare of Utah—Located in Clive, Utah, Envirocare is a commercial LLW disposal facility that began operations in 1988. The facility contains a mixed-waste treatment facility that offers stabilization, reduction/oxidation, deactivation, chemical fixation, neutralization, macroencapsulation, and microencapsulation. Waste is disposed of in aboveground-engineered disposal cells. Both public highway and rail provide access to the facility.

- Hanford Site—Located in Richland, Washington, the Hanford site, referred to as the Environmental Restoration Disposal Facility (ERDF), currently accepts MLLW for disposal in RCRA Subtitle C compliant land disposal units (mixed waste trenches) and in unlined units for MLLW. The site currently does not accept mixed waste from other DOE sites, pending completion of the Hanford Solid Waste Environmental Impact Statement (currently being prepared). The site is accessible only by truck.

- Nevada Test Site (NTS)—The NTS site is located in southwestern Nevada and has a total capacity of approximately 3 million m^3 (3,923,852 yd^3) with a projected operational design life of 100 years. Remaining capacity of the site is estimated at approximately 1.8 million m^3 (2,354,311 yd^3). The site currently accepts LLW and MLLW from DOE-Nevada (DOE-NV) activities and other approved generators. Approved generators are generally those defined as DOE sites and contractors that historically shipped waste to NTS. Waste profiles must be prepared and submitted to DOE-NV for each waste stream before disposal. Mixed LLW is unacceptable.

- Yucca Mountain—The Yucca Mountain facility, located in Nye County, Nevada, is under consideration as a permanent geologic repository for high-level waste and could provide a disposal option for irradiated fuel materials identified in the SDA inventory records. A portion of the facility has been built for testing purposes only.

- Waste Control Specialists—The Waste Control Specialists facility, located in Andrews, Texas, accepts LLW and MLLW for treatment. Waste disposal permits are pending. Currently, treated waste is returned to the generator or sent to another site for disposal if, after treatment, it still exceeds the exempt definition established by the Texas Administrative Code. Rail access is available directly to the site.

All the identified off-Site waste repositories have been retained to address the volume and variability of SDA waste. The WIPP facility in Carlsbad, New Mexico, is a primary element in developing retrieval alternatives as it is currently the only facility that can receive contact-handled TRU waste for disposal. Remote-handled TRU waste also will be accepted following approval of current RCRA-permit modifications. Currently, no sites are available that can receive HLW and MHLW for permanent disposal. For the disposal of LLW, both the U.S. Ecology site in Richland, Washington, and Envirocare of Utah in Clive, Utah, are currently licensed commercial facilities. The Barnwell site in South Carolina also is licensed for LLW, but its East Coast location would be logistically less desirable. The only site that is currently licensed to accept MLLW is the Envirocare site in Utah.

2.5.7.3 Disposal GRA Screening Summary. As discussed in preceding sections, a number of disposal options are available for waste and soil retrieved from the SDA. For this PERA, construction of an engineered onsite disposal facility was identified as the representative process option for disposal of retrieved LLW and treated MLLW and soil. The cost-effectiveness of on-Site versus off-Site disposal at one of the licensed facilities discussed in the preceding section, of all or a portion of the projected waste stream, should be further assessed during remedial design.

For retrieved TRU waste, off-Site disposal at WIPP was identified as the representative process option. For HLW and MHLW, no operating facilities are currently licensed to receive waste. It is assumed for this PERA that, if encountered, during retrieval activities, any HLW and MHLW would be classified and reburied in individual disposal units.

2.6 References

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